Management Techniques To Maximise Legume Production In Dryland Farming

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Abstract

A study was undertaken to evaluate the legume content in dryland pastures. Most dryland farmers continue to sow ryegrass/white clover pasture mixtures, but white clover fails to persist in drought conditions, leading to poor quality pastures. The objective of the study was to find out how much lucerne and subterranean clover are currently being utilised, to see which clovers are sown and the to assess the persistence of clovers, based on farmers' visual assessments of their pastures. A postal questionnaire was sent to 360 light land farmers in Canterbury and North Otago. The questionnaire focussed on pasture types, sowing rates, the use of greenfeeds, pasture management and animal carrying capacities on each property.

A total of 82 questionnaire responses were received (26%), 7 were discounted due to the small size of the properties, leaving 75 for the analysis. For the analysis of the results the respondents were stratified into those growing lucerne (n = 50) and those growing pastures only (n = 25). From the questionnaire respondents ten were selected for in-depth interviews, five that grew larger areas of lucerne and five that had predominately subterranean clover based pastures. The interviews and pasture assessments were conducted in October and November 2000.

The results showed that for the farms growing lucerne (66.7%) the average area is only 17% of the total farm area. The lambing percentage (survival to tailing) was 132% on lucerne farms and 117% on farms with 'no lucerne', but for the interviewed farmers growing lucerne the lambing percentage was 147%, with 124% for the no lucerne farms. The improved lambing percentage may be attributed to better ewe nutrition resulting in heavier liveweight ewes and the ability to flush ewes over mating. The predominant ewe breed was Border Corriedale (45% of the farms surveyed), Corriedale (24%) followed by Coopworth and Border Romney. The preferred sire was Polled Dorset (24%), Border Corriedales (22%) then Dorset Downs and Texels.

The white clover cover as a percentage of total pasture cover was estimated by farmers as being 21% in young pastures, but they estimated that this declined to 13% in older pastures. Ninety seven percent of the surveyed farmers sowed white clover in their pasture mixes at an average sowing rate of 2.35kg/ha. Farmers believed that white clover persisted in their pastures for 6.2 years on average, yet they only renewed their grass/clover pastures every 9.9 years for the lucerne farmers and 12.2 years for pasture only farmers. This implies that pastures are without white clover for

between one third to one half of the lifetime of the pasture. Red clover is sown by 38% of the farmers at an average of 2.35 kg/ha, but has little contribution to pastures at less than 1% of pasture cover on average. Only 32% of farmers sowed subterranean (sub) clover in their pasture mixes despite the fact they believed it persists for 15.4 years on average (beyond their current pasture renewal date). The farm owners visually estimated the sub clover botanical cover to constitute 11% in young and 6% in older pastures on the surveyed farms. On the interview farms, sub clover made up 41% of the pasture cover in young and 35% in old pastures. Meanwhile on the farms with no lucerne, sub clover was estimated to comprise 22% in young and 21% in the older pastures of the lucerne farms, when the farms were visited in mid/late spring.

The average area of winter greenfeed sown was 15 hectares (8% of farm area) for the sheep and beef farmers who did not winter graze additional stock, but 18 hectares (10%) for the sheep and beef farmers who wintered dairy cows or deer. The latter group represented 18% of all the farmers surveyed. Annual grass was the most commonly sown greenfeed type (25%), followed by turnips (18%) and then turnips and grass (14%). There was little difference in the area of greenfeed sown between lucerne and pasture only farms.

Key Words: drought, lucerne, white clover, subterranean clover, persistence, sowing rates, greenfeed, grazing management.

Glossary :

Dryland farms: Farms that are non-irrigated, on lighter (free draining and stony) soil types and are subject to agricultural drought conditions for more than one month most years.

Persistence: The ability of pasture species to actively grow and reproduce in dry environments.

Stock Unit (s.u) : The annual energy requirement of a 55 kilogram ewe producing one lamb per annum.

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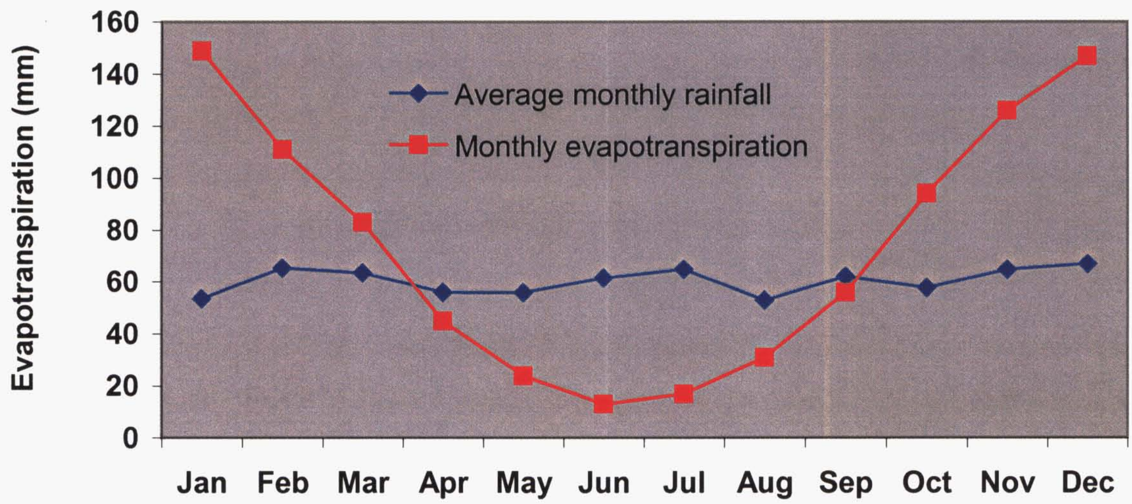
Chapter 1 General Introduction

The legume content in dryland pastures is considered lower than optimal for maximum animal production (Fraser and Keoghan, 1992). Low quality pastures result in reduced animal production, which leads to reduced farm profitability. Pasture legumes are important in New Zealand's pastoral grazing systems because they provide high quality feed for animal nutrition and fix nitrogen to enhance the production of companion grasses (Langer, 1982). Many dryland farmers continue to use ryegrass and white clover as their main pasture species, rather than sowing alternative, better adapted and persistent, productive legumes and grasses (Keoghan, 1991). White clover requires warm soil temperatures to become active, yet on many dryland properties on the east coast of New Zealand increased soil temperatures often coincide with drought conditions (Figure 1). White clover fails to persist in drought conditions, resulting in low legume content in older pastures (Fraser and Keoghan, 1992).

Figure 1: The long-term (1950-1997) average annual evapotranspiration and rainfall from dryland light Lismore soils at Winchmore Irrigation Research Station, Canterbury.



On shallow non-irrigated soils, in areas of low annual rainfall, subterranean clover (sub clover) is likely to be more productive than white clover, but less productive than lucerne (Langer, 1982). Lucerne is capable of producing at least 50% more feed than traditional pasture and contains greater crude protein whilst still vegetative (Douglas 1986, Black and Lucas, 2000). Both of these legumes can be viewed as alternative legumes that are more productive and more persistent than ryegrass/white clover for dryland properties with shallow stony soils in drought prone regions. To maximise herbage production, lucerne should be sown in the better free draining soils and the subterranean clover may be sown in poorer drained areas, soils with a non-permeable pan, or shallow soils over rock where it is not feasible to plant the deep rooted lucerne (Chapman and Williams, 1990).

Plate 1. An example of a young, highly palatable lucerne stand.

Plate 2. Peak spring production of 'Leura' sub clover and Cocksfoot.

1.1 Hypothesis

The pasture legume content in drought prone dryland properties is very low. The predominant pasture mix sown on dryland farms continues to be ryegrass and white clover, although white clover does not persist in drought conditions. Farmers have been reluctant to sow alternative legume species despite some obvious production advantages and so the current area of lucerne grown appears to be small. Dryland farmers with sub clover seed stocks in the soils are aware of the cool season production gained from having sub clover within their pastures, but are not including it within the pasture mixes that they currently sow.

The objectives of the current study were to:

- Review the literature currently available regarding the optimal pasture species choice to increase the quantity of forage grown, improve pasture legume production and to increase overall feed quality on dryland farms.
- Define the current pasture management practices adopted by farmers and their effect on the pasture legume content.

A literature review was conducted to assess the best management practices recommended for improving the legume content and productivity on drought prone properties.

Results from questionnaires sent out to dryland farmers, from personal on-farm interviews and from pasture observations in the field were used to quantify the actual practices used by farmers. The impacts of these management practices on the resulting pasture legume contents were interpolated from the collected data.

In the absence of large-scale lucerne growers, linear programming was used to simulate properties with either 17%, 50% or 70% lucerne, as well as to find the optimum mix of pasture and lucerne to maximise farm income. The model was based on the production parameters indicated by the questionnaire respondents.

Chapter 2 Literature Review

2.1 Introduction

Many of the farming regions on the east coast of New Zealand are summer drought prone. High quality pastures in New Zealand are thought to require a high white clover content (Langer, 1982). The competitive advantage of New Zealand sheep and beef farming is based upon the ability to feed animals throughout the year on low cost ryegrass and white clover pastures. White clover requires moisture and warm summer soil temperatures to reach its maximum productivity. However, warmer summers often coincide with drought conditions on the shallower, stony soils on the east coast of New Zealand and so white clover fails persist in dryland situations (Fraser and Keoghan, 1992). Lucerne has been shown to have an increasing production advantage over ryegrass and white clover as the rainfall levels decline (Keoghan, 1991). In dry seasons, with frequent dry winds and high evapotranspiration, the pasture growth from the ryegrass/ white clover swards can be minimal. Lucerne is capable of producing at least 50% more feed than traditional pasture and contains greater crude protein whilst it is still vegetative (Douglas 1986, Black and Lucas, 2000).

On shallow, non-irrigated soils in areas of low annual rainfall, subterranean clover is likely to be more productive than white clover, but less productive than lucerne (Langer, 1982). Lucerne should be sown in the better free draining soils to maximise herbage production and the subterranean clover may be sown in poorer drained areas, soils with a non-permeable pan, or shallow soils over rock where it is not feasible to plant the deep rooted lucerne (Chapman and Williams, 1990). However, for various reasons it is difficult to manage a farm with more than 50% of its area in lucerne. It is normal farm management practice to have about 10% of the farm area of dryland livestock farms in winter feed. If the farm has 50% of its area sown in lucerne, 10% in greenfeed then the other 40% must therefore be in the best perennial pasture available to complement the seasonal production of lucerne.

A major use of lucerne is for the provision of high quality hay or silage (or baleage and haylage). High quality lucerne hay has slightly higher digestibility than meadow hay and about twice the crude protein. Well made lucerne silage can have similar metabolizable energy (9.5-11.0 kgDM) and digestible organic matter levels (50-60%) as fresh lucerne (Drew and

Fennesssy, 1980). It is very wasteful to make lucerne into hay and silage when its greatest value is as fresh forage, as long as the animal demand can be made to fit the pasture production pattern. The need for conserved feed has declined over recent years with the improvements in feed management and the recent technological advances in irrigation (Figure 2) and greenfeed cultivars.

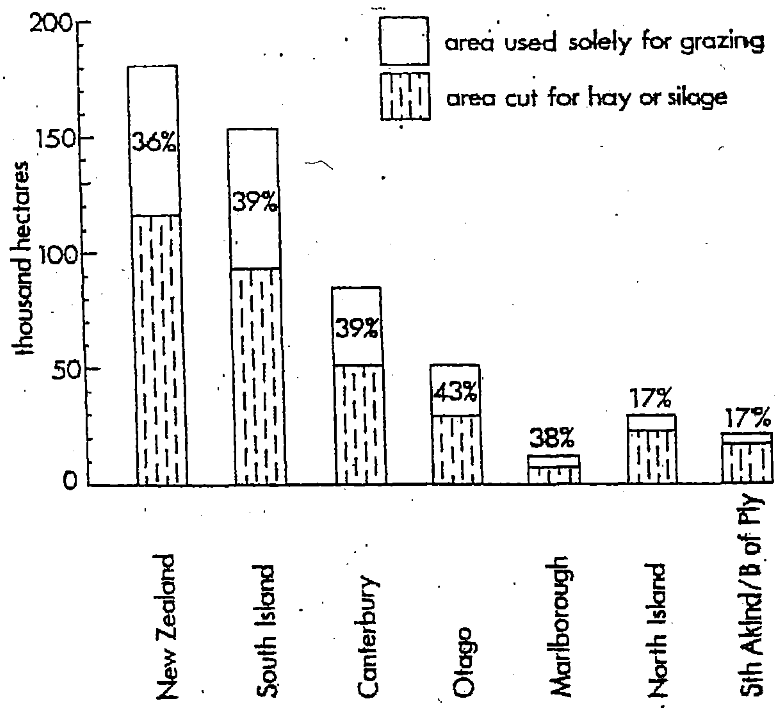


Figure 2: Area and utilisation of lucerne within major lucerne growing regions in 1979 (N.Z. Dept of Statistics).

Previously the popularity of lucerne increased after drought conditions over summer, as its productivity far exceeded grass/clover swards under dry conditions. The area sown in lucerne in New Zealand peaked at 220,000 hectares in 1975 when the government offered financial incentives for sowing it in drought prone areas. It was seen as good for maintaining stock performance in areas where pastures were adversely affected by grass grub (*Costelytra zelandica*) and drought (Douglas, 1986). By 1981, however, the area has declined to less than half the area of the 70's, with Canterbury still being the main lucerne growing region of New Zealand (Department of Statistics, 1981). However, despite producing 50% or greater herbage per year than traditional ryegrass/white clover, it still has not regained popularity with farmers, presumably because it requires specific management and as it cannot be grazed all year round.

In the early 1930's, sub clover came to be recognised in New Zealand as a pasture legume with superior cool season productivity and persistence in dryland areas compared with white clover. From the 1930's to the 1950's, the cultivars Tallerook and Mt Barker were extensively sown in the high country and shallow stony soils of both the North and South Islands. Since then the sowings by farmers have been sporadic and at low levels. Sub clover may be a superior pasture legume choice for dryland farms, with white clover having limited productivity and persistence in dry environments. There are now several newer low oestrogen sub clover cultivars, (both early and late flowering) available from Australia for New Zealand farmers. Unfortunately, without the plant breeding rights, commercial seed companies in New Zealand have, until recently seldom advertised or promoted the sowing of sub clover. New cultivars with plant breeding rights are now available from three New Zealand pasture seed companies.

2.1.1 Soils

The soils of New Zealand are divided into 73 soil groups based on variation in factors such as drainage status, parent material, chemical and physical properties (Molloy *et al.*, 1998). Large areas of the Canterbury region consist of more recent soils made up of Brown stony soils, Pallic soils and smaller areas of Gley and Recent soils (Figure 3). Drought occurs most frequently on the brown stony soils, which are characterised by varying amounts of stone in the topsoil and are generally free draining with a low water holding capacity. This low water holding capacity coupled with high evapotranspiration rates over summer results in severe limitations to summer pasture production.

2.1.2 Climate

Stewart and Taylor (1969) classified dryland farms as being in areas of the South Island that are subject to low rainfall (500 to 750 mm/year), with high summer evapotranspiration and consequent soil moisture deficits that impinge sharply on farm management systems. In this review dryland farms are defined as properties in farming regions where the evapotranspiration usually exceeds the rainfall for more than four months of the year and soil moisture deficits limit traditional ryegrass and white clover pasture production. The long term meterological data (1913 to 1986) shows that in Canterbury the evapotranspiration exceeds the rainfall for six months of the year resulting in agricultural drought conditions prevailing during the warm months (Winchmore Reasearch Station; Appendix 2).

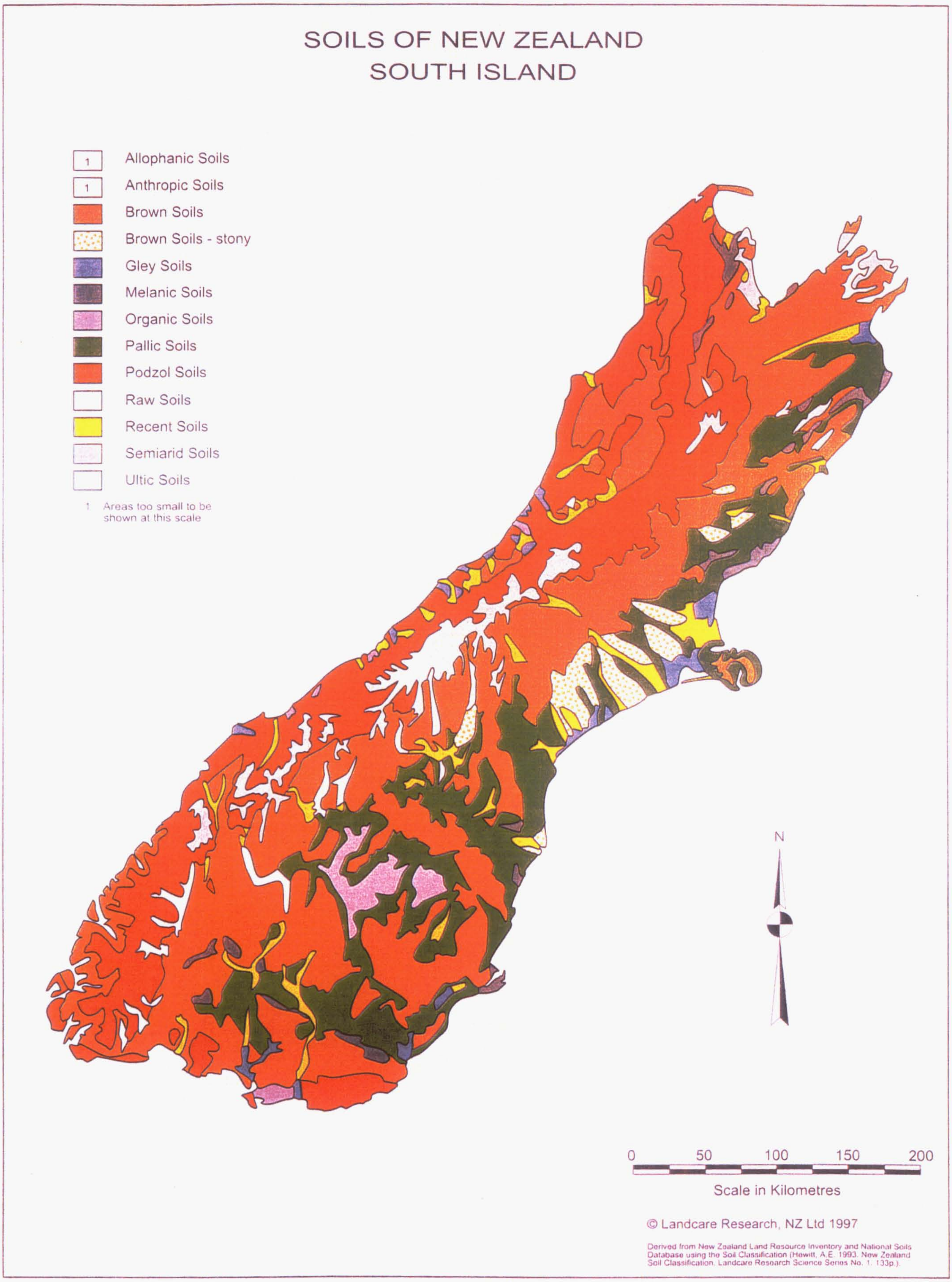


Figure 3: Soils of the South Island (Source: New Zealand Soil Classification, Landcare Research Science Series, 1).

2.1.3 The implications of drought on pasture legumes

Pasture legumes are important in New Zealand's pastoral systems because they provide high quality feed for animal nutrition and fix nitrogen to enhance the production of companion grasses (Langer, 1982). Of all the pasture legumes sown in New Zealand white clover is dominant species, as well as the species sown most frequently. The areas sown in the 1970's to 80's when clover seed exports peaked were far greater than they are at present. However, Hoglund (1990) showed that white clover failed to survive in dry summers in summer drought prone regions such as Canterbury. The failure of white clover to re-establish from seed may be partly explained by the effect of its low seed weight on seedling survival. It appears that seed weight is important for early seedling survival, it is not correlated well with long-term growth and survival in these drought-prone environments.

Clovers are weaker competitors for nutrients and moisture than associated grasses, yet nutrients and moisture are the main factors limiting pasture growth. Cultivation and sward renewal provide a means to improve clover performance, as both yield and nitrogen fixation may be greatly enhanced, but this option is not widely practised (Ball and Field, 1984).

Black and Lucas (2000) studied 'Grasslands Demand' white clover sown in 1994 with high endophyte 'Yatsyn' perennial ryegrass, 'Grasslands Wana' cocksfoot, 'Grasslands Advance' tall fescue, 'Grasslands Gala' grazing brome and 'Maru' phalaris into a deep fertile silt loam, under dryland conditions. The white clover contribution during the drought conditions of Feburary and March 1998 and in the summer of 1999 was as low as 4% and 1% of the dry matter in each respective month, despite favourable summer conditions in 1999. The mean white clover content ranged from 9% when sown with ryegrass and phalaris, to 1% with cocksfoot. The dominance of companion grasses has a large influence on white clover production.

2.2 High producing legume alternatives to white clover for dryland farms

In areas where soils dry below wilting point for short periods of a month or for several days in summer, deep tap rooted legume species are best adapted to maintain herbage productivity and quality (Saxby, 1956). Two legumes capable of high productivity and persistence are sub clover and lucerne, both of which are tap-rooted. As an annual clover, sub clover persists in these harsh environments by setting seed in late spring/early summer and remaining dormant in the soil until the arrival of autumn rains. Keoghan (1991) showed that lucerne has an increasing advantage in production as rainfall declines when compared with traditional ryegrass and white clover swards. In the early 1930's sub clover came to be recognised in New Zealand as a pasture legume with superior productivity and persistence in dryland areas. As a cool season active annual clover, sub clover is capable of providing high quality animal nutrition in early to late spring before setting seed and dying (Langer, 1982).

2.2 a Sub clover

Sub clover is a prostrate, tap-rooted plant which eventually puts out substantial runners up to 45cm long, with secondary and tertiary branches. Sub clover is a winter active annual clover originating in the Mediterranean area. It was originally accidentally introduced into Australia in the early 1800's having been brought in hay, straw and pasture seed. It was initially found along transport routes and stock camps and readily established in the favourable climatic conditions (Dear and Sandral, 1997). The plant is self-fertile, 2-4 seeds are enclosed by spiny sterile florets, forming a bur. This may be, depending on conditions, partly or wholly buried. Named for its ability to bury seed, its seedheads bend and are pushed into the soil surface after grazing. The plant then survives the summer in the ground as a seed. The seeds germinate in February/ March/ April, coinciding with the autumn rains. Flowering commences in mid spring or early summer, depending on the cultivar and by the end of December plants have set seed, dried off and died. The seed is large, purple/black in colour and is 10 times the size of white clover seed (140,000 seeds per kilogram). It is also oval shaped with a pronounced hilium.

Cultivars differ in their leaf size and the timing of flowering. Early flowering varieties such as 'Nunfarin' and 'Dalkeith' have evolved in areas of extreme climate where the growing season is short. In contrast, the newer late flowering Sardinian ecotype cultivars such as 'Goulburn', 'Denmark' and 'Leura' do not start flowering until September or early October in New Zealand and so have greater annual herbage production due to a longer growing season (Chapman and Williams, 1990). Flowering may span over six weeks or longer in good growing seasons (Dear and Sandral, 1997). The late flowering cultivars seem best suited to the growing conditions experienced on the east coast of New Zealand. Recent research by Lucas 2000 (*pers comm*) showed that 'Woogenellup' had the greatest productivity and persistence under the dryland conditions, when compared to 'Gouldburn', 'Karridale', and 'Seaton Park' sub clovers, along with 'Tahora' and 'Prop' white clovers. These trials were conducted during average winter and spring growing conditions at Ashley Dene, Lincoln University's dryland research farm in Canterbury,

Sub clover seed was first imported from Australia, but local production began in Marlborough in the late 1920's and seed was first certified in New Zealand in 1938 (Suckling *et al.*, 1983), but seed has not been produced in New Zealand for many years. The first commercial strain originated from 'Mt Barker' seed, imported from South Australia. This was the only seed sown in New Zealand up until the end of the 1930's, but since then 'Tallerook' has frequently been sown and in more recent times 'Woogenellup' has been oversown into existing populations. Suckling et al (1983) collected seed from 51 old pastures in 9 regions of New Zealand and discovered that 'Mt Barker', which contained high oestrogens constituted 74% of the total collection, 'Tallerook' 21% and 'Woogenellup' just 2%. Since the 1930's, there have been no New Zealand bred or registered cultivars (e.g. Table 1) largely due to the specialised machinery required to harvest the seed. Without the plant breeders rights New Zealand pasture seed companies have seldom promoted the use or sale of sub clover seed. Recently, however, three seed companies have gained plant breeding rights and have started to promote sub clover seed usage again.

Individual cultivars have different growth patterns, due to variations in flowering times, so certain cultivars may be sown to provide quality herbage during a particular period when quality stock feed is limited. For example, Chapman and Williams (1990) showed that 'Seaton Park' started to produce flowers on runners in early spring and produced 43% and 48% of its annual production in winter and early spring respectively. This would be valuable feed to sheep farmers lambing early (late June/July) to try and get the market premiums for spring prime lambs. The later flowering varieties 'Nangeela', 'Mt Barker' and 'Tallerook' produced 63, 68, and 71% respectively of their annual herbage production in spring and only 3-7% in winter. Therefore the cultivar choice will depend on when the feed is most required.

Variety	Formononetin level	Flowering starts	Flowering time index (days from sowing, mid May, to start of flowering)		Seed mature by	Minimum annual rainfall (mm)* for persistence		Hard seededness
			Perth	Wagga		South	North	
Nungarin	Very low	Early Aug	77	110	Late Sept	375	600	Very high
Dalkeith	Very low	Late Aug	97	120	Mid Oct	400	650	Very high
Seaton Park LF	Low	Early Sept	112	125	Late Oct	475	700	Moderate
York	Very low	Early Sept	112	125	Late Oct	475	700	Very high
Trikkala	Low	Early Sept	112	122	Late Oct	525	750	Low
Riverina	Low	Mid Sept	116	128	Mid Nov	500	700	Moderate
Rosedale	Low	Mid Sept	114	120	Early Nov	500	650	Moderate
Gosse	Very low	Late Sept	126	136	Late Nov	650	800	Moderate
Junee	Very low	Mid Sept	128	138	Mid Nov	500	725	Moderate
Woogenellup	Low	Mid Sept	130	140	Mid Nov	525	750	Low
Clare	Low	Late Sept	136	142	Late Nov	650	675	Low
Goulburn	Very low	Late Sept	140	145	Late Nov	525	775	Moderate
Denmark	Very low	Early Oct	144	149	Late Nov	600	850	Low
Leura	Very low	Early Oct	151	156	Early Dec	750	900	Very low
Nuba	Low	Early Oct	146	152	Early Dec	700	900	Moderate

*Rainfall figures are a guide only and will vary with aspect, slope, soil type and altitude.

Table 1: Most recent cultivars of subterranean clover available in New Zealand and their timing of flowering (Dear and Sandral, 1997).

2.2 b Lucerne

Lucerne is deep tap-rooted legume capable of sustained production of high quality animal nutrition in drier regions. It is capable of producing 50% or more feed than traditional ryegrass/white clover pasture and contains greater crude protein whilst vegetative. Lucerne can be looked upon as a major source of protein for ruminants for seven to eight months of the year, but it does require specific management to maintain productivity and persistence. The decline in the area of lucerne sown since the early 1980's was due to production losses caused by pests and diseases, which caused farmers to lose confidence in the longevity of lucerne stands. Attacks by blue green aphids (*Acrythosiphon kondoi*) and pea aphids (*Acrythosiphon pisum)*, stem nematodes (*Ditylenchus dipsaci* Kuhn), sitona weevils (*Sitona discoideus*) and spotted alfalfa aphids (*Therioaphis trifolii malculata*) devastated some lucerne crops in the 1980's. Since then, however, resistant varieties have been developed, but lucerne still has not regained popularity with farmers most likely because it requires specific management and cannot be grazed all year round. Lucerne is perceived by farmers to be expensive to grow and maintain, but an analysis of the cost per unit of crude protein or animal liveweight gain might prove otherwise (Appendix 3).

The incidence of disease in lucerne is increased by prolonged periods of wet weather. Lucerne growth in spring and early summer is directly linked to the soil temperature and solar radiation where water is non limiting. High rainfall summers will cool the soil temperatures and limit the sunshine hours, thereby lowering lucerne production. While lucerne yields can be greater in wet years or under irrigation with higher soil temperatures, its advantage over ryegrass/ white clover declines in wetter seasons. McCleod conducted three trials over the period 1971/72 to 1977/789 comparing yields of lucerne and ryegrass/white clover. Averaged out over the nine years lucerne out-yielded ryegrass/white clover by 51%. Yields in the three seasons with the highest rainfall in the lucerne growing season (1974/75, 1975/76, and 1976/77) corresponded to the lowest lucerne yield relative to ryegrass/white clover at only 19% extra, with 78% the greatest yield difference. Poor soil aeration or water logging can result in the death of the plant.

2.2.1 Production patterns

Most dryland farms of predominantly light soil types and in drought prone areas receive the majority of their income from sheep. The greatest feed demand on most sheep farms is during lambing, which generally occurs in late winter/early spring (August to September) on many low land east coast properties. With the rapid increase in sub clover growth from late winter to early spring dryland farmers may be best able to utilise sub clover production by lambing early and de-stocking before the onset of the summer dry period.

Another option would use sub clover based pastures for early spring feed, then rely on lucerne during the late spring/summer period. Whilst lucerne growth begins to increase in early September, Dunne et al (1999) showed total yield will be severely suppressed if it is grazed before late September/early October depending on soil temperatures (Figure 4). Dunne *et al.*, (1999) showed that the optimum time to commence grazing is when stem elongation is complete. This occurred at 40 cm plant height and when the plant had produced 16 nodes. Grazing before then severely reduced the overall spring lucerne production. Dunne *et al* (1999) demonstrated that lucerne had a high number of nodes when the plant was relatively short in late August, and as it developed the number of nodes increased slightly, whereas the plant height increased dramatically. Lucerne production accelerates rapidly by early October and may exceed 250 kg DM/ha/day at its peak in mid November, declining to around 40 kg DM/ha/day over summer/ autumn in drought conditions, until the end of May when growth is minimal over the winter months (Figure 4).

With correct management, lambing could commence on the sub clover based pastures, which would provide good quality forage in the late winter/early spring period when quality feed is limited and lucerne is still not able to be grazed. Generally traditional ryegrass/white clover pastures have slow growth rates in late winter/early spring, requiring warmer soil temperatures to become active. Later in spring, the increased soil temperatures may coincide with the onset of drought.

As subterranean clover has greater cool season activity, it is better able to utilise the available soil moisture before drought occurs. Sub clover germination occurs with the onset of autumn rains, usually February to April in New Zealand. Early growth is rapid due to the large seed. Winter growth is slow (30 kg DM/ha) but accelerates in early spring (August) and continues at a fast rate until flowering in late October/early November, depending on the variety. Both sub clover and white clover growth peaks in October, but sub clover peaks at 90 kgDM/ha/day compared to 50 kgDM/ha/day for white clover (Figure 4). In moist summers and autumns the annual white clover production will exceed that of sub clover, but in drier years white clover production and persistence declines (Langer 1982). Sub clover, being a cool-season active annual clover is better able to utilise the early spring soil moisture for production and becomes dormant at the onset of drier weather.

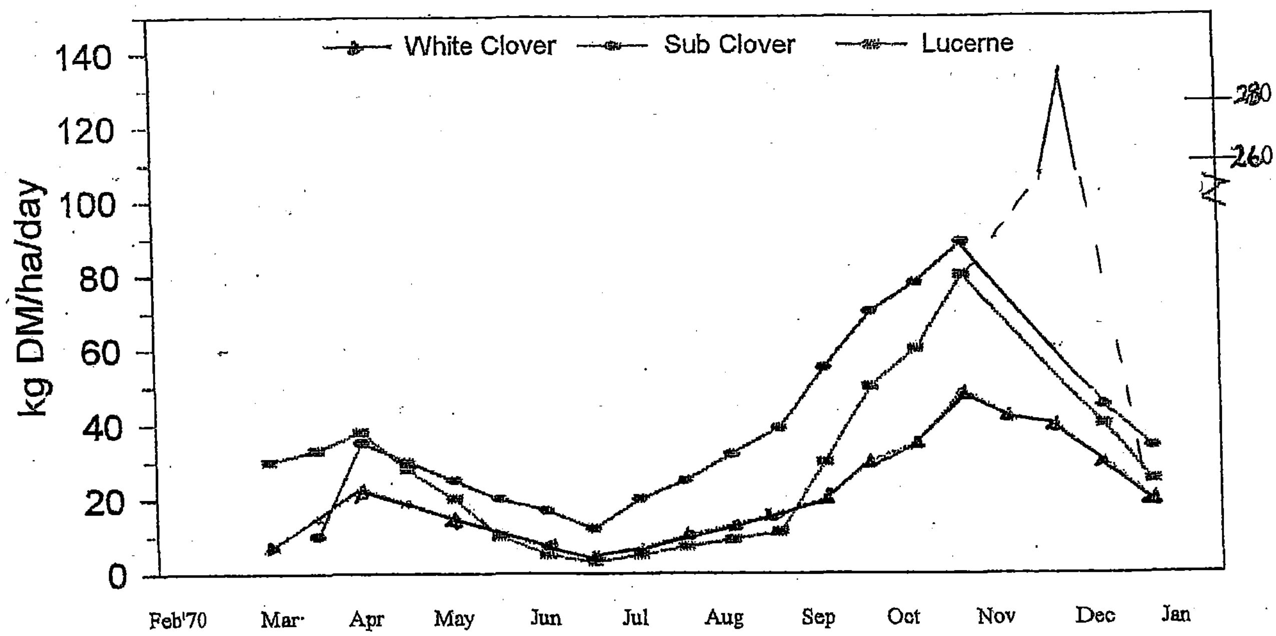


Figure 4: Herbage growth rates of pure legumes grown on shallow soils at Lincoln, New Zealand, in 1970-71. (Smetham unpublished).

More recently, Black and Lucas (2000) compared various pasture swards and lucerne sown on a deep, fertile soil. The pastures achieved 10 tonnes DM/ha from 3-year old dryland pastures, in the moist season of 1999/2000 compared to the 19 tonnes DM/ha from 3-year old lucerne during the same year in adjacent areas at Lincoln University (D.J.Moot *pers comm*). In a drier year, the difference between the two would most likely be greater. The lucerne in that experiment was sown into a deep Wakanui soil type, which suggests lucerne sowings need not just be in the stonier free draining soils. Indeed it appears they should be sown wherever possible on a range of soil types (provided they don't inhibit root development) to achieve maximum pasture production in the dry Canterbury Plains environment.

Lucerne uses water inefficiently, as it has a low stomatal resistance to water transpiration (Kerr *et al*., 1973). The drought tolerance of lucerne compared to ryegrass/white clover pasture comes from its ability to extract water and nutrients from a greater depth in the soil rather than an efficient control of water use by the plant itself (Evans 1977). The deep roots of lucerne allow it to persist in semi-arid areas of New Zealand (300-500mm rainfall) and on very free draining soils where perennial white clover is decimated by severe droughts (White and Meijer, 1978).

The difficulty for dryland sheep farmers is deciding when is the best time to lamb. For the farmer trying to lamb early, providing the ewes with sufficient feed and feed quality to maintain lactation is a problem. Autumn saved pastures tend to be lower in carbohydrate levels and lower in quality after winter frosts. The use of annual forage crops is another option. Many annual ryegrasses are more cool-season active than perennials and will provide sufficient early spring feed for lactating ewes but this is often low in digestible dry matter. Subterranean clover is able to provide the much needed protein and feed quality during this crucial early lactation period.

Another option for farmers is to delay lambing until the perennial pastures and in particular white clover, are actively growing in late September/ early October. However, if they choose to lamb later then there is the risk of drought, making finishing lambs all the more difficult. Furthermore, if they choose to lamb early then they have difficulty feeding the ewes adequately during the early lactation period. If lambs must be sold earlier due to a lack of feed, there is little demand for lambs sold as stores during drought years and so prices received are poor. Lucerne is an ideal pasture option for late lambing properties that are drought prone. Farmers may forego the early spring premiums by lambing later and finish lambs to heavier liveweights on lucerne, but would need to have a high proportion of the farm area in lucerne. By grazing lucerne, lambs can be fattened for longer, achieving higher carcase weights, which may compensate for any early spring premiums foregone, if they exist (Fletcher, 1976).

Subterranean clover can be a productive pasture legume in the east coast of New Zealand, where it is often too dry for white clover to persist. It can contribute up to 20% of herbage production in the cooler season. One of its disadvantages is the extreme variability in production from season to season. The variation may be partly attributed to autumn rainfall (Iversen,1957). Rickard and Radcliffe (1976) found the long-term average production of dryland subterranean clover based pastures, in low rainfall medium fertility sites, was around 5000 kg DM/hectare, with subterranean clover contributing an average of 23% of the total herbage.

Smetham (1995) compared subterranean clover in pure swards and in swards sown with perennial ryegrass. Subterranean clover contributed 1300 kg/ha to the mixed sward which totalled 6200 DM/ha, but it achieved 4000-5000 kg DM/ha when sown as a pure stand. The perennial ryegrass activity was low in the cool season when subterranean clover was most active. Smetham concluded that sub clover should be sown as a pure sward or sown with annual pasture species, that tend to be more cool-season active. However, the benefits (or otherwise) of this have not been researched. The maximum sub clover growth occurs in spring, with up to 85% of the total annual production occuring between September and November (Hastings and Drake, 1970). This sub clover spring production is more applicable to late flowering varieties, but will vary between cultivars depending on when they flower.

With sub clover producing good high quality vegetative growth until late October farmers may rely on sub clover to feed early lambs and have the majority of the lambs drafted as prime before November, when the sub clover herbage production declines. It takes approximately 100 days to finish lambs to the heavy liveweights that the European market requires, provided the lambs are fed a high protein and high allowance diet. If subterranean clover reduces its vegetative growth late October, depending on the cultivar and assuming it takes 100 days to fatten lambs, then lambing should commence in late July /early August on subterranean clover based pasture properties. However, if lucerne was available the lambing date could be later, the ewes and lambs could be grazed on subterranean clover based pastures, then the lambs weaned in mid October and fattened on lucerne.

2.2.2 Establishment

2.2.2 a Sub Clover

Sub clover seed should be sown in late summer/early autumn at around 9 kg/ha, which is enough to ensure good seedling numbers. If sown in spring the plant will not be mature enough in late spring to set seed and so it will perish. Regenerating subterranean clover has two main protection mechanisms to ensure plant survival if unseasonal summer rains occur. It has embryo dormancy, which is a temporary inhibition of germination until soil temperatures drop below 20^{o} C. The other mechanism is seed coat impermeability, or hard seed (Loftus Hills, 1944). At maturity the majority of the seed is hard, will not imbibe, although this impermeability is gradually lost over time depending on the ambient temperature regime (Quinlivan and Millington, 1962). The levels of hard seed increase when seeds mature in favourable moisture conditions. The hard seed guards against the loss of the plant population in unfavourable seasons. A proportion of the seed survives in the ground to germinate in subsequent years. High amplitude temperatures (greater than $15^{o}C$ in a day) have been shown to be the main factor responsible for breaking down the coating of the subterranean clover seed

(Quinlivan, 1965). The moderate to high diurnal fluctuations in soil temperatures on the lighter soils in Canterbury are sufficient for sub clover germination.

It is recommended that sub clover seed be sown in conjunction with diazinon prills if grass grub has been a problem within that paddock in the previous year. If not then spraying with Chlorophos or Gesapan 800EC in late autumn, for grass grub and aphid control will be sufficient (Langer,1990).

2.2.2 b Lucerne

Lucerne should be sown into a firm, fine seedbed. Ploughing is the recommended cultivation method to ensure the young seedling roots become established. Cover harrows should not be used at sowing. Sowing should be as shallow as possible, preferably 5-15 cm deep, ideally making good contact with the moist soil except where irrigation is available. Annual weeds can be eradicated by repeated cultivations, as can many perennial weeds. However, it is advisable to use a post emergence spray for weed control, if necessary, to eliminate weed competition while the lucerne is establishing (Langer, 1967).

Lucerne should be sown in spring. Elliot (1975) and Whitelaw (1975) showed that where moisture was adequate, establishment and seedling survival were greatest following October and November sowings and lowest in December. The average seeding rate has decreased over the years from 20 to around 11.5 kg/ha and research indicates that this could be further reduced to around 6 kg/ha if sowing freshly inoculated seed. Trials established at different sowing rates and plant spacings (Palmer and Wynn-Williams, 1976) showed that yields from established stands reach a maximum with plant densities as a low as 30 plants m^{-2}. Where higher sowing rates were used, the stands self-thinned over time to an equilibrium population above the minimum required for maximum production (Palmer and Wynn-Williams, 1976) (Figure 5).

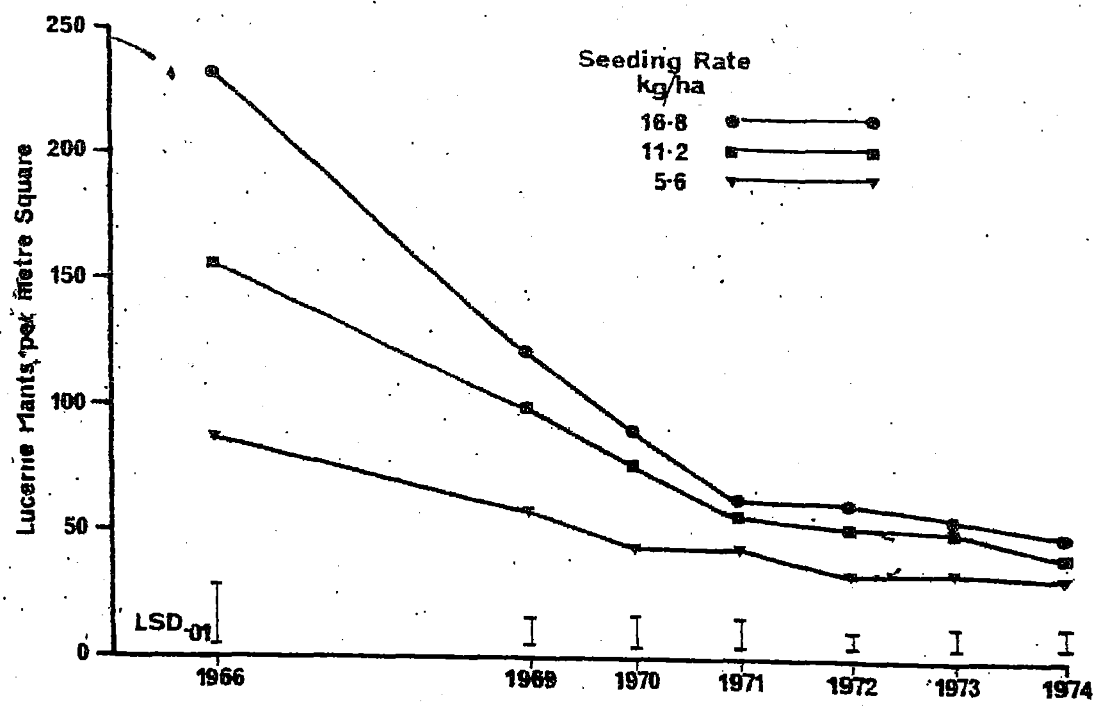


Figure 5: Seeding rates and lucerne density over time (Palmer and Wynn-Williams, 1976)

2.2.3 Soil Acidity

2.2.3 a Lucerne

Lime is an important factor in ensuring lucerne establishment and productivity. If the soil is below pH 6.0 lucerne nodulation will be greatly reduced. Lime is best applied 6 months prior to sowing, then mixed in during cultivation. Lucerne seed should be sown into a moist soil with the anticipation of rain or irrigation. Sowing into dry soils may result in reduced *Rhizobium* survival and consequently poor seedling emergence (Reynolds, 1969). In North America a pH of near 7.0 is required in much of the area where lucerne is grown (Rhykerd and Overdahl, 1972), but stands in New Zealand are grown on considerably more acidic soils. White (1970) showed that dry matter production was similar at pH 5.6 or 5.9, but significantly increased at pH 6.5. He found that cultivars differed in their relative responses to lime. Blair (1971) found that the average soil pH of 119 new sowings in Canterbury and Otago was only 6.0. Acid subsoils have been proven to restrict lucerne root development (White, 1967) but this may be due to aluminium toxicity rather than the acidity itself. Lucerne vigour dropped when the soluble aluminium levels within the subsoil exceeded 10 ppm and roots were generally absent where levels exceeded 15 ppm (J.A.Douglas, *pers comm*; cited in Douglas, 1986).

Theoretically, it is feasible to oversow prill-coated lucerne from the air and obtain persistent and productive stands (Douglas, 1970). To achieve good germination and establishment the soil surface needs to be rough or with some litter to provide some physical restraint to ensure the seed radicle pushes into the soil rather than along the surface (McWilliams *et al.*, 1970). Douglas (1970, 1974) recommended sowing early to mid August. Musgrave (1977) showed that lucerne establishment from oversowing was best when the soil temperature at 10cm depth was between 3°C and 7°C following sowing. This corresponds to August/ early September on sunny slopes and about a month later for shady colder slopes at higher altitudes. The seed used must be *Rhizobium* and lime pelleted and can benefit greatly from lime applications as low as 375 kg/ha at sowing (depending on the initial soil pH). To maintain the lucerne production on more acidic soils, regular lime and fertiliser applications are necessary, but this has now become uneconomical for most hill and high country properties. At lower altitude, on sunnier faces, lucerne may be established by direct drilling, which gives a more reliable establishment than broadcast seed (Janson and White, 1971).

2.2.3 b Sub Clover

Sub clover, by comparison, is capable of sustained production in medium fertility, acid soils with pH greater than 5.2. (Levy, 1936), but production is greatly enhanced by improved soil fertility. It proved to be an ideal legume choice for the high country areas of New Zealand. The use of aerial oversowing of pasture species and top-dressing with superphosphate in the 1940's and 1950's increased sub clover usage in the high country. The sub clover benefited from the added fertility from superphosphate increased production. Soils are known to acidify under sub clover based swards in proportion to the amount of nitrogen fixation, so lime will enhance production in low pH sites (Williams, 1980).

2.2.4 Fertiliser requirements

2.2.4 a Lucerne

The fertiliser requirements of lucerne reflect the usage of the crop. Up to 100% of the nutrients taken up by the crop may be removed if the crop is mechanically harvested as silage or hay and then removed. If the crop is grazed, up to 80% of the nutrients are returned as dung and urine (During, 1984). Large amounts of potassium are removed in hay or silage crops (Harris *et al.*, 1966). If regular crops are removed plant potassium levels should be monitored for deficiency levels (Sinclair *et al.*, 1984). Lucerne needs reasonable phosphate levels, sulphur, molybdenum and boron deficiencies should all be addressed to achieve maximum production out of the lucerne crop (Langer, 1990).

2.2.4 b Sub Clover

Sub clover production increases with increased fertility but it does not have the specific fertiliser requirements of lucerne, except for requiring potassic fertilisers if regularly harvested for hay (Williams, 1980). Without the deep, tap root of lucerne, sub clover can persist on low pH soils with a high aluminium content.

2.2.5 Nodulation

2.2.5 a Lucerne

Successful lucerne nodulation requires application of good growing inoculant to the seed and good inoculant survival allowing successful invasion of root hairs. Investigations suggest that nodulation may be very poor under New Zealand growing conditions. Sowing into dry soils may result in reduced *Rhizobium* survival and consequently poor seedling emergence (Reynolds, 1969). Ideally the inoculant must contain a minimum of 1.0×10^{10} viable *Rhizobia* per kilogram of seed to be inoculated at any time up to the expiry date (usually 6 months after manufacture). It must also be a pure culture of *Rhizobium meliloti.*

2.2.5 b Sub Clover

'Woogenellup' is one of the few sub clover strains to require a specific *Rhizobium* strain. Hasting and Drake (1970) demonstrated superior growth of 'Woogenellup' when associated with rhizobial strain CC2480a . Effective nodules are recognised by being larger, pink in the middle zone, and by the healthy appearance of the host plant. Ineffective nodules are white and scattered throughout the entire root system.

2.2.6 Pests and diseases

2.2.6 a Lucerne

A list of pest and disease resistant cultivars was published by Purves and Wynn-Williams (1994) (Table 2). Blue green and pea mosaic aphids can be a problem in lucerne. However, lucerne plants are able tolerate more aphids as the plant increases in size. It is at its most vulnerable in the early part of its regrowth or when it is growing slowly in autumn or winter. Kain *et al* (1979) suggested that aphid control should begin on young lucerne regrowth (less than 8 cm) when 5-10 aphids are present per stem, but once the crop has reaches 20 cm and is rapidly growing, it may tolerate up to 30 aphids per stem. Over-wintering aphids can be eradicated by grazing in mid winter before the shortest day.

Grass grub can also be a problem when establishing lucerne, so if sowing into a paddock previously infected with grass grub (*Costelytra zealandica*), then sowing with Diazinon prills is recommended. Lucerne seedlings up to six months are highly susceptible to root damage by grass grub larvae (Pottinger, 1976). East *et al* (1980) suggested that the larvae are only likely to be present after inadequate cultivation following a pasture or pasture seed crop. Lucerne established by oversowing, direct drilling or minimum tillage is more prone to such attack from grass grubs and slugs (Baker, 1990; Baker, Saxton and Ritchie, 1996; White and Meijer, 1978). The use of Diazinon prills at sowing will control aphid numbers until late spring. If aphid numbers in late spring are severe, then spraying with Chlorophos or Gesapan 800EC is suggested. The same sprays are recommended for aphid control in established crops. Pest monitoring groups give warnings during seasons or conditions when aphid numbers are likely to escalate.

Table 2: Lucerne cultivars available in New Zealand (compiled by Purvis and Wynn-Williams, AgResearch, Lincoln, Februrary 1996).

Cultivar	Dormancy	Resistance to pests and diseases							
		BGA	PA	SAA	BW	SN	PRR	VW	LD
G. Otaio	I	R	R	R	R	R	R	-	S
G Kaituna	I	R	R	R	R	R	R	-	MR
G. Oranga	SD	R	R	R	R	S	S	MR	MR
WL 320	SD	MR	R	R	R	MR	R	MR	-
WL 322 HQ	SD	MR	R	R	R	MR	R	R	-
WL 323	SD	-	R	MR	R	R	R	R	R
AS13 R+	A	S	SR	R	R	R	R	S	S
P. 5444	D	S	MR	R	MR	SR	SR	R	-
P. 5454	D	MR	R	R	R	MR	R	MR	-
P.5717	A	R	R	R	SR	SR	R	SR	-
Washoe*	SD	S	MR	R	R	R	R	S	S
Wairau	SD	S	S	S	S	S	S	S	S

Key to table

* = Becoming unobtainable

Dormancy or Winter activity

D = dormant ; SD = semi-dormant; I = intermediate; A = wniteractive

Pests and diseases

BGA = blue-green aphid; PA = pea aphid; SAA = spotted alfafa aphid; BW = bacterial wilt; SN – stem nematode; PRR = Phytophthora root rot; VW = Verticillium wilt; LD = leaf diseases.

Levels of resistance

R = resistant; MR = moderately resistant; SR = slightly resistant; S = susceptible; - = not tested.

2.2.6 b Sub Clover

In Australia, sub clover experiences several pest, disease and virus problems, but it appears few of them are present in New Zealand. Sub clover is susceptible to grass grub damage. In addition, blue green aphids and Sitona weevil will reduce overall plant vigour and seed production. Tolerant cultivars exist but none are resistant (Langer, 1990). Some cultivars are susceptible to clover stunt virus, plus root rot in wet environments, but otherwise sub clover has little pest or disease problems in New Zealand (Langer, 1990).

2.2.7 Quality and Palatability

2.2.7 a Lucerne

The gross chemical composition of grazed lucerne varies according to its stage of growth (Bailey *et al.*, 1970; Joyce *et al.*, 1972; and Jagusch *et al.*, 1976). The ratio of stem to leaf increases as the plant matures and the associated chemical changes result in dramatic decreases in digestibility (Fletcher, 1976). Lucerne grown as a leaf crop has a high proportion of crude protein and provides a valuable feed source for ruminants (Hove and Bailey, 1975). Lamb growth rates in excess of 400 grams per day have been recorded from newly weaned young lambs that were allowed to selectively graze lucerne (Cruickshank, *et al.*, 1985). Cattle grazing lucerne achieve up to 1.0 kg liveweight per day provided they graze to residual levels no lower than 15-20% (Croy and Weeda, 1975). Fresh lucerne is seldom used by dairy farmers in New Zealand. However, milk from lucerne grazed cows results in lower fat, protein and lactose levels in early lactation, but higher yields in mid and late lactation compared to cows fed pasture (Bryant, 1978). In areas where lucerne had a 50% greater dry matter production advantage over pasture (typical east coast dryland dairy farms) increasing the lucerne area on dairy farms by 32% resulted in 45% more production per cow and 61% per hectare (Mace and Patterson, 1979). Sodium supplement further increased the production from lucerne fed cows (Joyce and Brunswick 1975).

Animal growth rates tend to decline in the autumn, especially if the crop has been allowed to flower in February /March. Then the plant will switch from being vegetative to building up the carbohydrate root reserves. Lucerne should be allowed to achieve 50% flowering once over summer, to achieve maximum spring production the following spring, but it may be at the expense of feed quality in autumn of the current season (D. Moot *pers comm*). The digestibility of the lucerne leaf remains relatively constant at 73-75%, but as the plant matures the digestibility of the stem declines (Fletcher, 1976). To achieve rapid lamb growth in spring allowances of 3.5-4.0 kg per head daily of lucerne leaf were required (Jagusch *et al.*, 1979,1980). To achieve rapid growth in lambs on mature lucerne over summer and autumn, lambs should only graze long enough to remove the leaf component of the crop and the less digestible stem fraction remaining be fed to stock which are not being finished (McKiney *et al.*, 1970). To obtain the best utilisation a 'follower and leader' grazing policy is recommended. Once lambs are weaned they graze the lucerne first and remove the highly digestible leaf fraction follow by the dry ewes to eat the remaining leaf and stem. Lucerne crude protein level declines as the plant reaches greater maturity and the proportion of leaf decreases (Jagusch, 1972). This reflects the decline in proportion of leaf at 35% crude protein compared to stem at 14% (Thom *et al.*, 1980).

Fresh lucerne has been used in cattle feeding in limited amounts. The best results came from cutting, wilting and then grazing to avoid the potential for bloat in cattle (Croy and Weeda, 1975). Grazing gives higher crude protein yields than cutting (Allison and Vartha, 1973) presumably from dung and urine returns, as a similar response can be gained from an application of nitrogen fertiliser (Allison and Vartha, 1973).

Lucerne under stress from pests and diseases is known to depress the ovulation rates in sheep, due to the oestrogens it contains (Coumestrol and 4 meth-oxycoumestrol) (Kelly and Lindsay, 1975; Kelly *et al.*, 1976). Loper (1968) and Kain and Biggs (1981) have shown elevated coumestans in plants severely infested with aphids. Nielson and Don (1974) believed aromatization can occur in response to stylet probes and salivation of insects, thus stimulating phytoalexin synthesis. For flushing and mating, ewes should graze younger or healthy, undamaged lucerne to avoid oestrogen interfering with ovulation and conception.

2.2.7 b Sub Clover

Some sub clover cultivars contain oestrogens, but in New Zealand there have been no reports (J.W. McLean *pers comm*, cited in Chapman and Williams, 1990) of reduced fertility, probably due to the low contribution of sub clover to the total annual herbage production. Flushing and mating generally occurs in autumn in New Zealand, when the subterranean clover is just beginning to germinate or establish.

There has been little research conducted on the nutritive value of sub clover in New Zealand. In South Australia sub clover is grown with annual grasses for animal forage or as a pure species. Lamb growth rates of 250-300 grams per day for lambs and 1.05 kg/day for cattle in winter and spring have been measured. The nutritive value of sub clover declines rapidly from mid spring (60-72% digestibility) to late spring/summer when it becomes reproductive (36-45% digestibility) (Fitzgerald, 1979). Many farmers feed lactating ewes on annual grasses or brassicas, which have low carbohydrate and protein levels in the late winter/early spring period (Drew and Fennessy, 1980). Sub clover is actively growing during this time and has greater protein and digestibility than the conventional feed type used. This makes it an ideal forage for lactating ewes or early weaned lambs.

2.2.8 Sodium deficiency

A problem associated with lambs grazing lucerne leaf is a sudden death syndrome termed 'redgut' (Gumbrell 1974, 1983). Rapid passage of highly digestible feed through the forestomach results in increased fermentation in the large intestine and causes it to move position in the abdominal cavity, leading to complete torsion of the intestinal mass and death. In Canterbury, in 1983, 1-3% of lambs died from redgut annually whilst grazing lucerne (Gumbrell, 1983), The incidence is reduced in suckling lambs or in weedy lucerne crops. In contrast to natrophyllic ryegrass and white clover, lucerne is a natrophobe, concentrating sodium in its root rather than vegetative parts (Smith *et al.*,1980). Weeds have been shown to have up to 10 times the sodium concentration of lucerne (0.03-0.04%) (Jagusch *et al.*, 1977). The low sodium content of lucerne plays an active part in the incidence of redgut, which may be reduced by the use of salt licks (Jagusch et al 1977), or by allowing lambs access to pasture or other forage with higher sodium. Recent studies by A. Nicol (*pers comm*) suggested a strip of pasture around the lucerne paddocks to allow grazing animals access to 70% lucerne and 30% ryegrass/white clover is sufficient to meet the animal sodium requirements.

Minimum levels of sodium for satisfactory nutrition of grazing ruminants fed pasture mixes are: sheep 0.07 %, beef animals 0.10 %, and dairy cows 0.12 % of dry matter respectively. Low sodium levels are seen in the Central Plateau, Central Otago and Canterbury. It is recommended that lucerne fed animals be supplemented with salt licks to assist in sodium uptake.

2.2.9 Grazing Management

2.2.9 a Lucerne

Iversen (1967) laid the foundation for the grazing management of lucerne in New Zealand. His four-day grazing, followed by 36 days spelling rotation gave consistently good results. Jansen (1978) observed that lucerne yielded 14% less under a 15 day grazing duration than a 2-4 day system over 8 months. This meant larger mob sizes were needed. White's (1982) recommendations are now taken as most practical. He advocated spelling for 42 days and grazing for durations of up to 10 days. This may vary with the season, depending on the development of crown shoots, which can be damaged if the grazing duration is to long. The root carbohydrate reserves of lucerne plants fall to a minimum at around 13 days after harvest and then rise to a peak after 40 days when actively growing (Hodgkinson, 1970). Carbohydrate and dry matter accumulation in roots reflects the severity and timing of defoliation (Wolf, 1978).

Since lucerne is a long day plant requiring approximately 12 hours of daylight at temperatures of 17 to 22^0C, flowers are not initiated in the first spring growth period (Thomas, 1967). It is recommended that lucerne stands be allowed to reach 50% flowering once only over summer. The plant transfers its energy at flowering from vegetative growth to the buildup of carbohydrate levels in the roots, which provides the energy for the following springs plant production (Moot *pers comm*). Accumulation of carbohydrate reserves is important in autumn to counter the effects of cool season defoliation (Chatterton *et al.*, 1977). Decline in plant vigour following repeated defoliations in winter leads to death in some plants and low spring production in those remaining (Fulkerson,1970). All grazing and weed control should be completed before the shortest day because the plant will begin to develop crown shoots from then on. A hard winter grazing of lucerne in early to mid June is recommended to control over-wintering aphids. However, if the soils are wet this may lead to plant damage (Dunbier *et al.*, 1982; Smallfield *et al.*, 1980). If grazing is commenced again at the end of September then the spring production will not be compromised (Dunne *et al.*, 1999).

2.2.9 b Sub Clover

Sub clover production is enhanced by set stocking which reduces the competition from pasture grasses for light, nutrients and moisture. Earlier flowering strains, if grown in a pure stand, are lower in seed yields than the later ones, provided sufficient soil moisture is available. An evaluation in New Zealand of the longevity and production of subterranean clover (*Trifolium subterraneum* L) cultivars in dry north facing hill country recorded general superiority of late flowering cultivars, over early or mid season flowering cultivars (Chapman *et al.*, 1986). Only in very dry environments, such as North Canterbury, where moisture deficits occur from early spring onwards, were late flowering varieties disadvantaged. With sub clover being an annual, seed production is important for the plant's production and persistence. Choosing a suitable variety for a given area and climate often determines how much seed is set. Although leaf size and flowering date influence cultivar performance, the differences in stem growth, flower and burr production affect the seed set and persistence of the plant. The later that plants flower, the greater their opportunity to exploit favourable growth conditions in spring.

2.2.10 The importance of the timing of grazing

2.2.10 a Lucerne

The timing of the first spring grazing of lucerne has a marked effect on the total spring herbage production. Janson (1975) showed that delaying grazing until early October increased spring yield by 24%. Studies by Dunne *et al.* (1999) at Lincoln University, showed that the optimum time to commence grazing is when stem elongation is complete. This occurs at 40 cm plant height and when the plant has produced 16 nodes (Figure 4). Lucerne has a high number of nodes when the plant is relatively small. In Dunne *et al* (1999)'s experiment the number of nodes increased slightly, whereas the plant height increased dramatically. This indicated that stem elongation was occurring and the internodal length was increasing.

Dunne *et al.*, (1999) also showed that during autumn flowering the carbohydrates produced are stored in the root system for the following spring's growth. In comparisons between irrigated and non-irrigated plots given the same grazing treatments, they found that dryland plots had greater spring growth. This was attributed to the dryland plots maturing earlier and flowering for longer in the previous autumn. By not reaching 50% flowering over summer, the irrigated lucerne carbohydrate buildup in the roots was compromised resulting in lower plant production in the following spring compared to the dryland plots.

2.2.10 b Sub Clover

In the first year of sowing sub clover pasture swards in sites where no subterranean clover previously existed, it is important to remove grazing stock and to keep them off until the plant has dried off. This allows for maximum seed production. Once the seed is in the ground grazing management can be more relaxed. Set stocked subterranean clover has the ability to flower and produce seed close to the ground. It is important not to graze stands too closely until lateral shoots begin to run. If grazed hard within two months of germination, sheep may eat below the cotyledons and leaves resulting in seedling mortality.

Over-grazing in autumn will kill subterranean clover plants, but once the plants have produced runners, in mid winter, grazing may be hard. In the first year after sowing, grazing should cease when flowering commences to ensure maximum flower and seed production. In the subsequent years, pastures should be managed to minimise competition from resident grasses by intensive grazing, a light grubbing or sprayed with Glyphosate in autumn when the clover seeds are about to germinate.

2.2.11 Weed control

2.2.11 a Lucerne

Lucerne has been shown to be more sensitive to competition at establishment than other commonly sown legumes (Campbell, 1968; 1974). Thus the use of a herbicide to reduce competition during establishment is essential. Cullen (1965), Douglas and Kinder (1973) and Vartha (1973) showed clearly that lucerne sown with perennial ryegrass does depress the lucerne yield. Lucerne should be sown as pure stand and sprayed to remove grasses. 'Preside' is recommended to remove any flat weeds or 'Galant' to remove grass. Both are safe to use during the lucerne spring growth period when the weed numbers are greatest. Lucerne production is greatest when sown as a pure stand. Lucerne sown alone out yields lucerne-grass mixtures (Baars 1980). Vartha and Fraser (1978) showed that irrigated lucerne, direct drilled annually with annual ryegrass had poor survival after 3 years direct drilling, depending on how it is grazed.

The elimination of perennial weeds prior to sowing, such as couch (*Agropyron repens*), onion twitch (*Arrenatherum elatius*), yarrow (*Archillea millefolium*), docks (*Rumex spp.*) and other grasses, is essential, since no satisfactory control is available once the crop is established. Two weeks after grazing, just before mid winter, the crop can be sprayed with 'Paraquat' and 'Atrazine'. The 'Atrazine' is moisture dependent, so should be sprayed in moist soil conditions or when rain is likely. The 'Paraquat' becomes rainfast after 3 hours. The use of 'Paraquat' and 'Atrazine' in winter will control annual weeds such as storksbill, poa annua, shepherds' purse, chickweed, barley grass, vulpia as well as sub clover in established lucerne stands. Other commonly sprays used in winter to control weeds are 'Centurion Plus', 'Targa', 'Gallant', 'MCPA', 'Dicamba', or mixes of each. The timing of the spraying is important, spraying beyond the shortest day may prove detrimental to the lucerne spring production. Weeds in established lucerne are seldom a cause of stand decline, but rather a consequence of lower plant vigour due to some other factor, such as incorrect frequency and/or prolonged grazing (Langer, 1973). In older stands weeds may prove beneficial to correct any sodium deficiency in grazing animals.

2.2.11 b Sub Clover

On lucerne properties the use of hormonal herbicides to control weeds in lucerne crops can severely reduce the seed set of sub clover (Gregan, 1982). Autumn spraying with 'Glyphosate' before the sub clover seedlings germinate will inhibit the growth of the resident pasture plant species in spring allowing the clover to extend larger runners and produce more nodes. The resulting clover vigour leads to greater herbage production and seed set in the first year.

2.2.12 Companion pasture species

2.2.12 a Lucerne

Lucerne should be sown without companion grasses to achieve maximum productivity and persistence. When a lucerne stand begins to run out, it may be direct drilled in grass to improve the annual dry matter production and reduce the likelihood of weeds invading the lucerne. Lucerne and grass have different grazing requirements, so if sown together as a new stand the grazing management will benefit one species and not the other. The combined production would be less than if the lucerne and pasture swards were sown and managed separately (Langer, 1990).

2.2.12 b Sub clover

The growth of sub clover declines when grown in conjunction with perennial ryegrass with a high portion of plants infected with the wild type endophyte (*Neotyphodium lolli*). A pot experiment conducted by Latta and Quigley (1993) showed that the density of sub clover declined when sown with high endophyte perennial ryegrass. The endophyte levels had no effect on germination, but as the endophyte levels in the growing medium increased the nodulation scores of the sub clover declined.

Sub clover is capable of transferring large amounts of nitrogen to companion plants relative to its total nitrogen fixation levels (Table 3). This transfer means increased production from the companion grasses but then they may also compete with the sub clover for light and nutrients. However, the grass dominance is suppressed by set stocking. Lucerne fixes more nitrogen in total, but the transfer to the surrounding soil or companion plants is similar to sub clover. High yielding crops of lucerne have given annual herbage nitrogen (N) yields of over 700 kg/ha under dryland (Sinclair *et al.*, 1977) and irrigation with the N yield being increased by about 20% through the use of fertiliser N (Allison and Vartha, 1973). However, as Table 3 indicates, the transfer of nitrogen to the soil is relatively low.

	Total N fixed	Soil	Recovery 1st year	Recovery 2nd year
New Zealand (Brock 1973)				
White clover	570	130	92	68
Lotus	590	200	78	76
Suckling clover	265	75	56	66
Australia (Simpson 1976)				
White clover	475	190	30	
Lucerne	510	120	16	
Sub. Clover	250	100	50	

Table 3: Recovery or transfer of Nitrogen (N) to grasses from various forage legumes (kg N/ha/yr) (Gregan, 1982).

Shading reduces the rate of leaf production in sub clover, results in lower inflorescence numbers, reduced rate of flowering and therefore lower seed production (Rossiter 1978). Sub clover production is greatest under set stocking where the shading is minimised. In summer, drought prone areas, white clover acts as an annual and, therefore, must compete with more vigorous late flowering cultivars of sub clover. Trials by Hill and Gleeson (1990) showed that white clover can survive severe competition from sub clover as a seedling. In years with summer rainfall white clover competition will severely reduce the germination and successful establishment of sub clover seed.

2.2.13 Persistence

2.2.13 a Lucerne

The productivity and persistence of lucerne stands declines rapidly with poor grazing management (O,Connor and Vartha), which will lower the carbohydrate reserves in the roots and the plant vigour will decline markedly. Wet or poorly aerated soils may lead to plant death (Figure 6), so good site selection and preparation is important (Palmer 1982). Another contributing factor to low stand persistence is a lack of lime and fertiliser applications resulting in a lowering of the soil pH (Stephen, 1964). D. Moot (*pers comm*) showed that lucerne in a deep fertile soil is capable of producing in excess of 19-21 tonnes DM/ha, but to sustain that level of production nutrients regular fertiliser and lime applications are necessary to optimise the plant production. Pests and diseases may also contribute to a weakened lucerne stand (Stephen *et al.*, 1982).

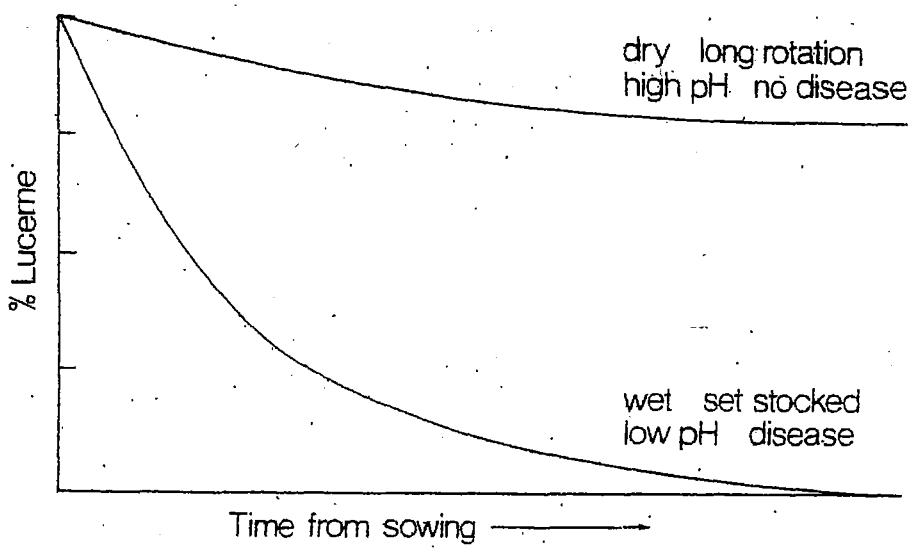


Figure 6: Lucerne content of stands over time from sowing under different conditions without herbicide usage (Palmer and Wynn-Williams, 1976).

With the newer more resistant varieties, pests and diseases are less of a problem. As lucerne stands decline in vigour (generally in 8-12 years on dryland properties, if managed properly) the gaps become large enough to let in summer weeds and perennial grasses (Palmer and Wynn-Williams, 1976), unless continually sprayed. At this point, an alternative to spraying for weeds would be to overdrill grass into the lucerne to postpone renewal by 1-3 years. The increase in pasture production depends on the success of the overdrilling, the grass species sown and subsequent grazing management.

2.2.13 b Sub Clover

To maintain sub clover persistence, average seed production must exceed 600 kg/ha annually. If the seed matures under favourable conditions, a high proportion will be hard seed (50-90%) and will not germinate in the first autumn. This leaves enough seed in the ground if there is an autumn germination failure. Once germinated, the seedling relies on sufficient moisture being available or it will die. Autumn failures (false strikes) are generally caused by poor autumn rains and low autumn temperatures (Smetham and Wu Ying, 1991).

To maximise germination, autumn sowing is recommended (Langer 1990). A light surface working with a grubber in January will kill a proportion of the ryegrass plants and create a soil tilth to encourage the germination and establishment of subterranean clover seedlings (Langer 1990). Herbicide application in autumn will speed up the attainment of good seed stocks in the ground. Autumn spraying with 'Glyphosate' will inhibit the growth of the resident plant species in spring allowing the clover to extend larger runners and produce more nodes. The resulting clover vigour leads to greater herbage production and seed set in the first year. A flower is produced at each leaf axil and a set of flowers per node, so the greater the number of nodes, the greater the seed set. The timing of sowing should coincide with autumn rainfalls. February appears to be the ideal time for sowing in much of New Zealand's summer dry hill country (White, 1970). Sub clover plants are frost tolerant, but frosts over flowering or a lack of high temperatures to induce flowering, can reduce the total seed yield. This can cause natural limitations to the areas suitable for planting. Above 914 metres height in the South Island is believed to be the subterranean clover altitudinal limit (Smetham *et al.*, 1980).

2.2.14 Paddock management

Subterranean clover is seen as a weed in lucerne pastures. It smothers the lucerne in early spring and can severely reduce the spring yields. A large proportion of subterranean clover seed can be killed by deep burial through ploughing, which is the recommended method for preparation of a lucerne seed bed. The small proportion of subterranean clover seed that may be left can be enough to suppress the lucerne production in spring, particularly in cold wet springs.

2.2.15 Recent research

Much of the literature currently available on lucerne is from the 1980's or earlier. This reflects the relative decline of interest in lucerne research until recently and that the focus on agricultural research is now generally more orientated towards bio-technology as opposed to looking at on-farm systems.

More recently Purves and Wynn-Williams (1994) released a list of pest and disease resistant cultivars. The only other relevant recent information on lucerne came from Dunne *et al.*, (1999), who showed that during 50% flowering over summer results in increased carbohydrates stored in the root system to improve following spring's production.

With sub clover, much of the early research emphasis in New Zealand was based on establishing the benefits of sub clover in the hill and high country of New Zealand. It is only recently that some research has been conducted on the importance of the more recent cultivars of sub clover to all New Zealand pastoral farmers in drought prone areas.

2.3 Discussion

In 2000, the total lucerne seed produced for re-sowing in New Zealand was 30 tonnes nationally. The local market is so small that seed companies are placing little emphasis on the development of better varieties. Hence the popularity of an old varieties such as 'Wairau', which is susceptible to most pests and diseases. Many of the newer, more productive varieties are being imported from America.

White (1982) recommended that in areas where lucerne has a production advantage over pasture, then up to 50-60% of a farm area should be in lucerne, despite the fact the management difficulties increase. His recommendations were based the production figures obtained from the Ashey Dene dryland farm belonging to Lincoln University which was sown in up to 70% lucerne during the 1970's. For many years, attendances of 500 people or more at their annual field days reflected the interest in grazing lucerne.

There has recently been a large growth in the dairying industry in the South Island of New Zealand. Dairy farmers tend to avoid using lucerne in their production systems because of potential bloat problems and the lucernes need for more precise management than the traditional ryegrass/white clover pasture mix. With its high protein content, lucerne would be an ideal feed source for dairy cattle if used in conjunction with other pasture feed types. It is possible that spending half a day grazing animals on pasture and the other half day on lucerne could increase milk yields. If dairy farmers were to use lucerne, then the local market would become larger and seed companies would look at developing new varieties suitable for New Zealand conditions. However, lucerne may not persist well within the dairying system due to the use of irrigation and the greater frequency of grazing (which must be at 35-52 day intervals for lucerne) and due to hoof damage to the plant crown by cows. In the United States, lucerne (alfalfa) is set-stocked by dairy cows and lasts longer than 5 years. Currently much of the lucerne seed development by New Zealand commercial seed companies is for export into the expanding Latin American market.

2.4 Conclusions

On farms that are up to 50% or more lucerne dominant, the other 50% is likely to be in grass/clover pasture and annual crop forage. Good grazing management is very important, for both the lucerne component and the grass/clover component in order to avoid grazing the lucerne beyond the shortest day in winter through till the end of September. A combination of sub clover based pastures and lucerne would greatly improve the total legume production and greatly reduce the annual fluctuations in pasture production (O'Connor *et al.*, 1968). Sub clover provides high quality feed in August and September when lucerne should not be grazed. Later flower varieties of sub clover peak in production in October, this may allow for some lucerne to be conserved without compromising lamb production.

Sub clover is seen as a weed in lucerne paddocks often smothering it in early spring. The best solution to this problem may be to manage the total farm as two separate entities. No subterranean clover should be sown in the area allocated for lucerne and as a part of the lucerne rotation or renewal programe each paddock will go through a pasture or brassica phase. At no stage should subterranean clover be used in any sowings, so that no hard seed can be deposited in the soil to smother the early spring lucerne production. This area of the farm would be ploughed because ploughing is the best cultivation method to ensure the lucerne plants get their roots established.

If the rest of the farm was allocated for sub clover based pastures, surface working and sowing in autumn to establish pastures would be recommended. Langer (1982) suggested a light surface working with a grubber in January/February every four years in established pastures to reduce the ryegrass dominance, to create a soil tilth and allow light to penetrate to the newly germinating subterranean clover seedlings, after weakening the grass. This appears the best method of ensuring a high sub clover content in the pastures. One sowing of sub clover at the recommended 9 kg/ha followed by good pasture management should be sufficient to build up the soil reserves of hard seed to ensure its persistence.

Lucerne should be sown on the best land available on the property and ryegrass/ sub clover based pastures on the rest. Each area should be managed according to the different plant grazing requirements to ensure their production is not compromised. By managing the farm as two distinct areas for the lucerne and sub clover, dryland farmers would have the opportunity to maximise their pasture productivity and longevity whilst optimising the pasture quality, even during dry years.

White clover, or other clovers, may still be sown to take advantage of more moist summers, but seed reserves of white clover will still exist in the soil for some time. My recommendation would be to sow the recommended sub clover seed first and then look at white and red clover if it is required. The amount of sub clover seed required depends on the level of hard seed already present in the soil, the volunteer sub clover in brassica crops gives an indication of the seed populations.

In the current study, a questionnaire was constructed based upon the literature available and the results showed that in summer dry conditions white clover failed to persist. The literature, along with pasture seed sales figures, suggests that farmers in these drier regions still continue to rely on white clover as their major pasture legume for provision of high quality feed and boosting ryegrass production by nitrogen fixation.

Chapter 3 Materials & Methods

3.1 Introduction

A postal survey was chosen as the most practical method of gathering information from a large number of farmers. A comprehensive questionnaire, covering most aspects of pasture and animal management was sent to 360 dryland farmers from Otago and throughout Canterbury. Ten farmers were then selected from the questionnaire respondents for in-depth interviews.

3.2 The Postal Questionnaire

The final questionnaire was developed using terminology with which farmers would be comfortable, whilst trying not to sacrifice any of the required information (see Appendix 1 for a copy of the complete questionnaire). The questionnaire was pre-tested on five farmers as a pilot study, the results of which indicated some deficiencies. The deficiencies were then corrected and the questionnaire was ready to be sent to farmers.

3.3 Recipients of the Questionnaire

Compiling a list of farmers' names to send questionnaires proved difficult. The final list used comprised a combination of names provided by Primary Industry Management members and a list of farmers who attended a series of lucerne seminars run throughout the South Island by Dr Derrick Moot of Lincoln University, in conjunction with BASF and Genetic Technologies Limited (Pioneer Seeds). A total of 360 questionnaires were sent to farmers in early August, accompanied by a covering letter. A further 317 reminder questionnaires were sent in early September, with the cut-off point for replies being December 1st. Of the 360 farmers sent questionnaires, 320 were dryland farmers, the rest were seed merchants, small block holders and retired farmers.

A total of 82 (26%) utilisable responses were received, which was less than initially anticipated. The low response rate was possibly due to the fairly large size of the questionnaire and the fact that it was not sent out until early August when many dryland farmers had started lambing and were very busy. The questionnaire was compiled in May, but the delay in sending was due to the difficulty in compiling a list of farmers' names. To try to increase the response rate, all respondents went into the draw for a Lincoln University Year 2,000 Budget Manual and Technical Manual. No farms smaller than 50 hectares were included in the results of this study, thus of the original 82 utilisable responses 7 were discounted, leaving 75 for the analysis of the results. Of the 75 farmer questionnaires able to be included in the analysis, 50 grew some lucerne and 25 grew no lucerne.

The questionnaire focussed on the following areas:

- The influence that an increased reliance on lucerne has on the timing of lambing
- How the subterranean clover based pasture portion of the property is managed
- Whether the pasture management is based around one pasture species as opposed to another
- The timing and intensity of grazing for each pasture species

General questions regarding cultivation methods, the amount of feed conserved, plus the amount and types of greenfeed crops sown were also included to try to assess the effect of pasture supply (particularly during the winter and the dry summer months) on the overall stock carrying capacity. Farmers were asked to visually assess the legume content of their pastures based on the percentage of pasture cover occupied by legumes.

3.4 Selection of interviewees

From the 75 utilisable questionnaire responses, ten farmers were selected for in-depth interviews regarding their pastures, cultivation methods used and their pasture and animal management. The ten farms selected for interviews were based on the following criteria:

- Five of the farms grew approximately 30% lucerne and had predominantly subterranean clover based pastures.
- The other five farms had 50% or greater in subterranean clover based pastures

All of the farms selected were properties large enough so that the farm income was the principal income source.

3.5 Interview process

The interview process involved the author interviewing the farmers on their properties, followed by personal visual assessment of the pasture paddocks for pasture cover, pasture vigour, estimated percentage of clover in the pasture cover, weed numbers and general pasture stand vigour. The farm paddock inspections were carried out in the last two weeks of October 2000, during good spring pasture growing conditions. The interviews and pasture data were recorded manually, then later transferred to a spreadsheet for analysis. The interviews were conducted using a pre-written questionnaire as a guideline, but the forthcoming nature of the farmers interviewed meant that they covered a far greater area of interest than just the questionnaire and many accompanied the author on the farm paddock inspections. The enthusiasm and willingness of these farmers to share knowledge proved to be one of the most rewarding parts of this study.

3.6 Analysis

3.6.1 Questionnaire/ Survey

The main factors regarding pasture and farm management to arise from the responses to survey questionnaires were collated, the means calculated and trends plotted where appropriate.

For the analysis, the results from surveyed and interview farms were compared and for both groups the farms subdivided into those grew lucerne and the farms that grew no lucerne.

The average lambing dates for both the interview and survey groups were calculated by converting the starting date for lambing into a number using a Julian calendar. The mean number was calculated for each group then converted back into a calendar date.

3.6.2 Interviews

The interview results were analysed using the same techniques used for the survey. The two sets of results were compared and any differences were highlighted.

3.7 Farmer identities

In order that the identities of the farmers interviewed remain confidential, their names shall not be used in this report. All farmers involved in the study were given an identity number for analytical purposes.

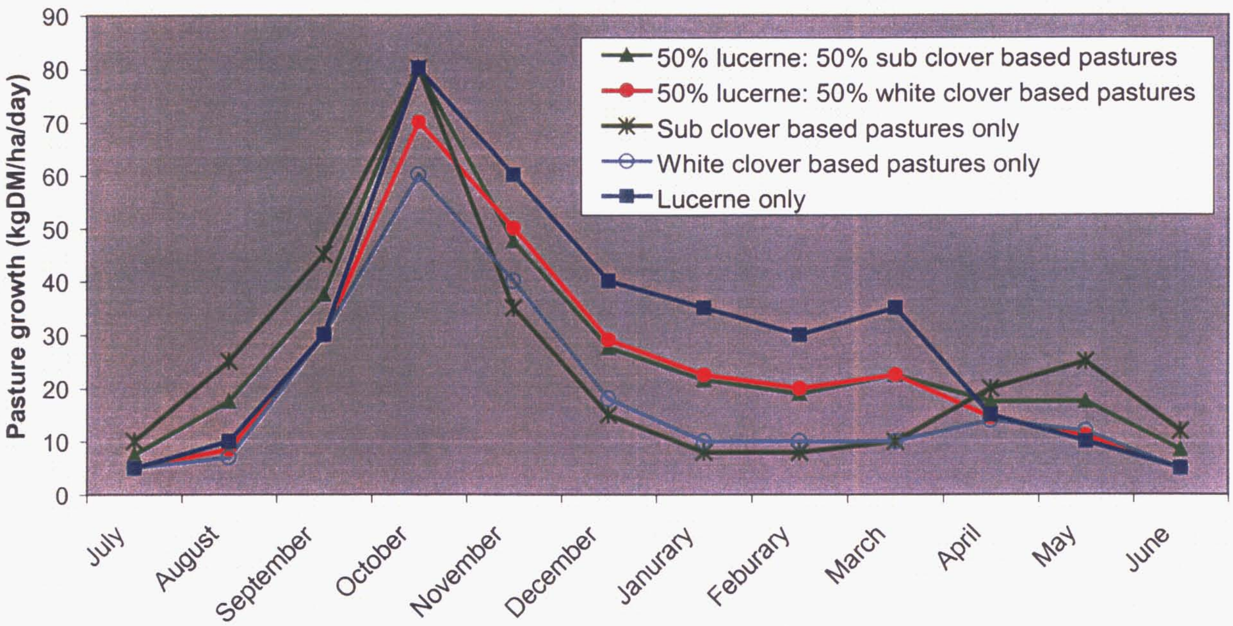
3.8 Linear programming

The optimum lucerne/pasture balance to improve farm profitability was found using a linear programming model. The simulation model used was the 'Solver package' available in Excel as part of the Microsoft '97 office suite. A good guideline for the use of this package is found in the book 'Farm Planning with linear programming: concept and practice' (Dent *et al.*, 1986).

The linear programme was used to simulate for four lucerne area options: 17% of the farm area in lucerne (the average area grown on the surveyed lucerne farms), 50% lucerne 70% and the optimum area determined by the model to give the maximum total farm gross margin. Of these farm areas, 17% represents the average area currently sown in lucerne, 50% is the largest area of lucerne that can be sown without creating winter management difficulties and 70% is the area of lucerne that was previously sown at Ashley Dene, Lincoln University's dryland research farm. The changes in total farm gross margin resulting from changing the lucerne areas sown can be established from the model.

The model was based on a 400 hectare property running 3,500 ewes, achieving 135% lambing (tailing %) breeding its own replacements and selling all lambs prime at between 14 and 16 kg carcase. The pasture options were lucerne, ryegrass/white clover, ryegrass/sub clover, summer greenfeed and winter greenfeed. Each feed type was given an estimated annual variable cost of production and all animal maintenance costs were included. The model was used to find the greatest farm gross margin from all the pasture options available. The solutions found by the model are based on 100% pasture feed utilisation, which is unlikely in reality. However the model does show with some degree of accuracy the relative differences in the farm gross margin between the various pasture composition options. The pasture production growth rates used in the model are taken from Douglas (1986) who was the last author to publish comparable lucerne and ryegrass/white clover production in a quotable scientific manner on the same soil type in dryland conditions. There was no current New Zealand literature available comparing sub clover based pastures with white clover based pastures and lucerne. The sub clover pasture growth rates used are the authors own estimates based on the literature and climatic conditions expected on these dryland properties. Figure 7 shows the expected pasture growth curves from a paddock growing lucerne only, 50% lucerne and 50% ryegrass/sub clover, 100% sub clover and 100% ryegrass/white clover based Douglas (1986) results (Table 4). During moist summers the growth rates of lucerne, ryegrass and white clover may increase by up to 50% more than the annual production shown in Table 4.

Figure 7: The pasture growth curves for some the permanent pasture options available to dryland farmers.



Lucerne is capable of providing 50% more production than ryegrass/white clover pasture, but it does so only for seven months of the year. Pasture management and the use of winter greenfeeds is generally geared around providing feed for ewes over winter and early spring before the lucerne can be grazed in late September. This is in contrast to pasture, which may be grazed throughout the year.

Table 4: The expected pasture growth from lucerne, ryegrass/white clover and ryegrass/sub clover on light soils under Winchmore dryland growing conditions.

		Dry matter Production (kgDM/ha/day)				
	Number of Days	Lucerne	Ryegrass/ White clover	Summer greenfeed	Ryegrass/ subclover	Winter greenfeed
January	31	35	10	0	8	0
February	28	30	10	0	8	0
March	31	35	10	0	10	10
April	30	15	14	0	20	15
May	31	10	12	0	25	14
June	30	5	5	0	12	8
July	31	5	5	0	10	20
August	31	10	7	0	25	20
September	30	30	30	34	45	0
October	31	80	60	50	80	0
November	30	60	40	34	35	0
December	31	40	18	15	15	0
Annual Production (kgDM/ ha/yr)		**10 805**	**6 732**	**4115**	**8 947**	**2664**

Chapter 4 Results

4.1 Survey questionnaire results

The survey data results presented in Table 5 are based on the 75 usable farm responses from farms above 50 hectares in size. The average area of the farms was 313 hectares with a mean of 289 effective hectares (based on farmers' estimates), while the average stock wintered was 8.7 stock units per effective hectare. The rainfall mostly ranged from 550 mm to 770mm annually, although one farm had annual rainfall of 1000mm. The overall mean annual rainfall was 680mm per year.

The majority of the properties surveyed were on lighter free-draining soils, although some did have pockets of heavier, more productive land. The stone content of the soils on the survey farms ranged from 5-50%. Of the 50 farmers that grew lucerne, 64% ploughed their pastures, 26% surface worked, while only 10% used direct drilling. Amongst the remaining 25 farmers who grew no lucerne only 44% used ploughing, 36% surface worked and 20% direct drilled after herbicide application.

From visual assessments, the farmers estimated that the average percentage of clover cover in younger pastures (2-3 years old) is around 21% which declines to an average of 11% in older pastures (8-10 years old). The corresponding percentages for sub clover in pastures were 11% in young and 5.6% in older pastures. The farmers believed that white clover persists for an average of 6 years compared to 15 years for subterranean clover. Meanwhile red clover was believed to have a negligible contribution to pasture production and a perceived low persistence.

For those farmers who did sow clovers:

- 97% (n =73) sowed white clover at an average sowing rate of 2.2 kg/ha.
- 64% of lucerne (n = 48) and 58 % (n =15) of no-lucerne farmers sowed no red clover. [For farmers who did sow red clover, the average was 2.4kg/ha on lucerne and 2.2 kg/ha for no-lucerne].
- The least sown species was sub clover, with 71% (n = 53) of lucerne and 64% (n = 16) of the no-lucerne farmers sowing no sub clover. Of the farmers sowing sub clover, the average rate was 2.6 kg/ha on lucerne and 2.8 kg/ha sown on no-lucerne properties.

The average lambing date was earlier (August 19th) on farms that grew no lucerne as compared to the September 6th for those with lucerne. Over 60% of the lucerne farmers surveyed had split lambing with a smaller mob that lambed on average 6 weeks ahead of the main mob. The average lambing date for the main mob was (September 6th).

4.2 Interview results

A total of 10 farmers were interviewed, 5 with a large proportion of the farm in lucerne and some subterranean clover pastures and 5 with a large area of subterranean clover based pastures. In general, the farms with 'no lucerne' were larger, averaging 517 hectares compared to 358.2 hectares for farms with lucerne. However, one of the farms with no lucerne was 1000 hectares, which tended to bias the average farm size. Of those growing lucerne, the average farm area in lucerne was 15% with 30% lucerne being the highest proportion. The average stock units wintered on properties not growing lucerne was 9.66 (su/ha) compared with 9.28 su/ha on lucerne properties.

The estimated white clover cover in young pastures on farms growing lucerne averaged 23%, but declined to a mean of 3% in older pastures. The white clover cover on non-lucerne farms remained relatively constant over time, with 9% in young and 8% in older pastures. The proportion of sub clover on lucerne farms also appeared to remain fairly constant over time at 22% in young and 21% in older pastures. On the non-lucerne farms, the sub clover cover was estimated to be much higher at 41% in young and 35% in older pastures.

- The white clover seed sown averaged 2.8 kg/ha on lucerne and 1.8 kg/ha on no-lucerne farms
- Red clover sowings averaged 2.1 kg/ha on lucerne and 2.6 kg/ha on 'no lucerne' properties
- Sub clover seed was sown at an average of 2.0 kg/ha on lucerne and 2.3 kg/ha on no-lucerne farms.

The farmers interviewed believed white clover persisted for 4 years on average, red clover depended on the season, whilst they perceived sub clover to persist for 20 years or more.

The preferred cultivation method for lucerne farmers was ploughing, with 80% (n = 4) choosing that option. Only one farmer (20% or n = 1) preferred to spray and surface work. No lucerne farmers interviewed used direct drilling for their lucerne or pastures. The non-lucerne farmers interviewed also mostly (60% or n = 3) preferred to plough with one (20%) spraying and surface working and one (20%) spraying then direct drilling.

Table 5: Summary of results from the survey questionnaire.

(Farmers' estimates)

Mean farm area		313 hectares
Mean % effective area		289 hectares
Mean % of farm effective area in lucerne		17%
Mean % of farm effective area in white clover		50.8%
Mean % of farm effective area sub clover		24.5%
Mean stock wintered/effective area		8.69
Lambing date range		10th July –17th Oct
<u>**LUCERNE FARMS:**</u>		
Mean lambing date- lucerne farms		September 6th
Overall lambing %		121.3%
Mean lambing % with lucerne		123.2%
Farmers' estimates of pasture clover cover:		
Mean % white clover in young pastures-lucerne farms		20.9%
Mean % white clover in older pastures-lucerne farms		12.5%
Mean % sub clover in young pastures-lucerne farms		9.6%
Mean % sub clover in older pastures-lucerne farms		5.4%
Clovers sown in pasture mixes:		
Mean white clover sowing rate		2.22 kg/ha
Mean red clover sowing rate		2.35 kg/ha
Mean sub clover sowing rate		2.55 kg/ha
Age of pastures when renewed – lucerne farms		9.9 years
Cultivation method – lucerne	Plough	64%
	Spray and surface work	26%
	Spray and direct drill	10%
<u>**'NO LUCERNE' FARMS:**</u>		
Mean lambing date – farms with no lucerne		August 19th
Mean lambing % with no lucerne		116.9%
Farmers estimates of pasture clover cover:		
Mean % white clover in young pastures-no lucerne farms		20.5%
Mean % white clover in older pastures- no lucerne farms		14.2%
Mean % sub clover in young pastures-no lucerne farms		14.8%
Mean % sub clover in older pastures-no lucerne farms		6.0%
Clovers sown in pasture mixes		
Mean white clover sowing rate		2.27 kg/ha
Mean red clover sowing rate		2.23 kg/ha
Mean sub clover sowing rate		2.78 kg/ha
Age of pastures when renewed-lucerne farms		9.9 years
Cultivation method - no lucerne	Plough	44%
	Spray and surface work	36%
	Spray and direct drill	20%
<u>**MEAN RESULTS FOR BOTH FARM TYPES:**</u>		
Years white clover persists		6.2 years
Years sub clover persists		15.4 years

Table 6: Summary results from the ten farmers interviewed.

(Personal estimates - some in consultation with farmer)

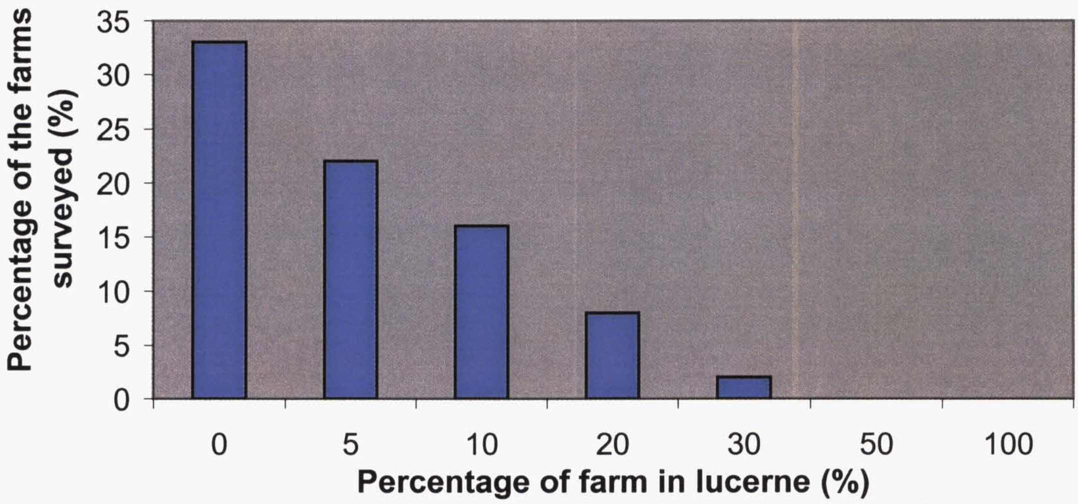
Mean farm size		437.6 hectares
Mean lucerne farm size		358.2 hectares
Mean 'no lucerne' farm size		517.0 hectares
Mean effective area		415.5 hectares
Mean effective area in lucerne (% of farm)		15.1%
Mean effective area in white clover (% of farm)		69.8%
Mean effective area sub clover (% of farm)		14.8%
Mean stock wintered/effective area		9.47 s.u.
Stock wintered/effective area- lucerne farms		9.28 s.u.
Stock wintered/effective area- farms with no lucerne		9.66 s.u.
Lambing date range		10th July – 1st Oct
Mean lambing date – lucerne farms		August 10th
Mean lambing date – farms with no lucerne		August 19th
Overall lambing %		135.1%
Mean lambing % with lucerne		146.6%
Mean lambing % with 'no lucerne'		123.6%
LUCERNE FARMS:		
Mean % white clover in young pastures		23.0%
Mean % white clover in older pastures		2.8.%
Years white clover persists		3.8 years
Mean % sub clover in young pastures		22.0%
Mean % sub clover in young pastures		21.0%
Years sub clover persists		11.6 years
Mean white clover sowing rate		2.8 kg/ha
Mean red clover sowing rate		0.80 kg/ha
Mean sub clover sowing rate		2.33kg/ha
'NO LUCERNE' FARMS:		
Mean % white clover in young pastures		8.9%
Mean % white clover in older pastures		8.0%
Years white clover persists		4.3 years
Mean % sub clover in young pastures		40.5%
Mean % sub clover in young pastures		34.5%
Years sub clover persists		20.0 years
Mean white clover sowing rate		1.8 kg/ha
Mean red clover sowing rate		1.4 kg/ha
Mean sub clover sowing rate		1.4 kg/ha
Cultivation method – lucerne	- Plough	80%
	- Spray and surface work	20%
	- Direct drill	0%
Cultivation method - no lucerne	- Plough	60%
	- Spray and surface work	20%
	- Direct drill	20%

4.3 Comparative Results

4.3.1 Areas of surveyed farms in lucerne

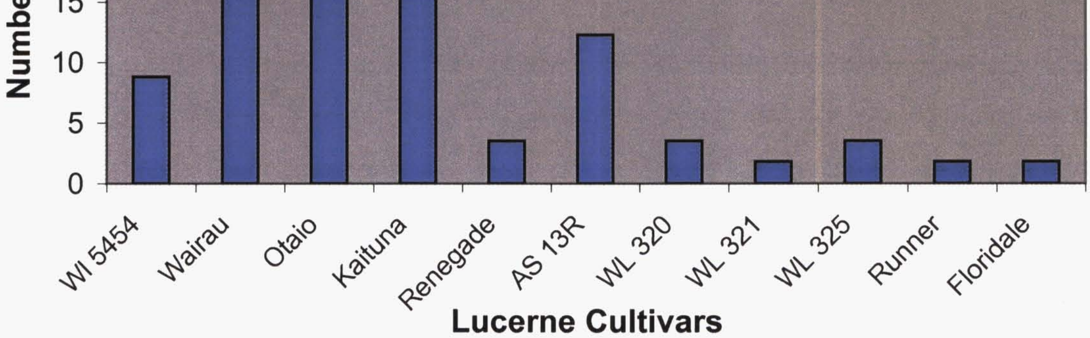
For the 50 (66.7%) farms surveyed that did grow lucerne, 17% of the farm was the average area grown. The largest area grown on the surveyed farms was 30% (Figure 8).

Figure 8: The percentage of the total farm area grown in lucerne for the surveyed farms.



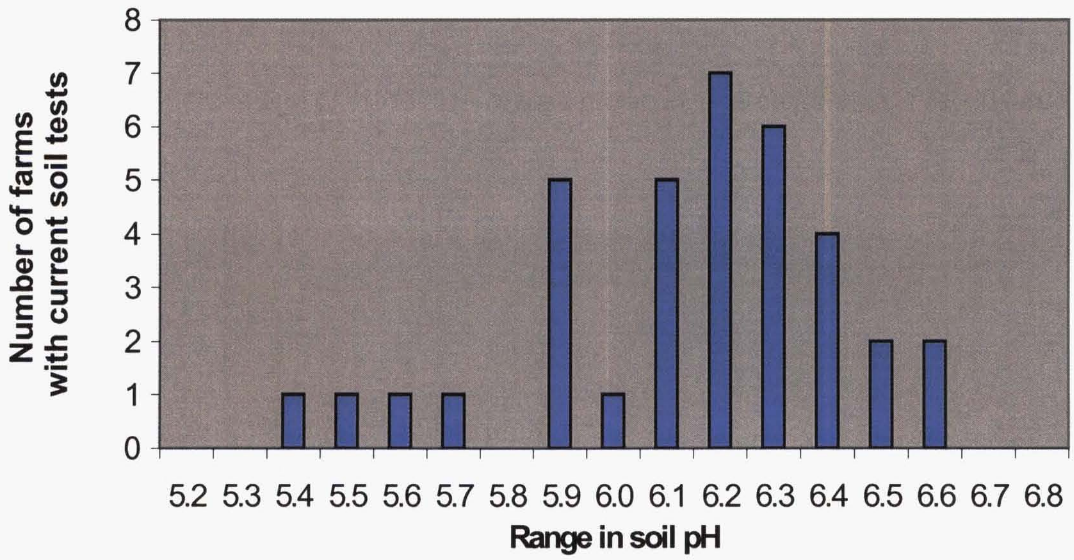
Of the surveyed farmers that grow lucerne, 32% grew the cultivar Wairau, 16% Otaio and Kaituna, 12% AS13R, 9% Pioneer WI 5454 (Figure 9).

Figure 9: The lucerne cultivars grown on the surveyed farms.



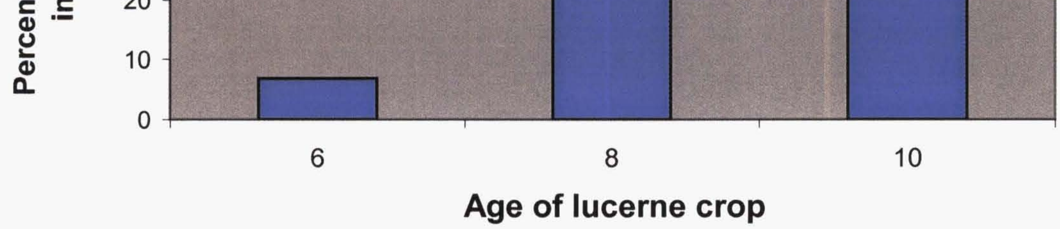
The surveyed farmers were asked in the questionnaire for their most soil tests results for the paddocks currently growing lucerne. The results show that the soil pH levels ranged from 5.4 to 6.6 with a mean pH of 6.14 (Figure 10).

Figure 10: Survey results showing the range in soil pH for lucerne paddocks.



The average age when lucerne was renewal occurred was 8.9 years (Figure 11).

Figure 11: The age of lucerne crops when renewed by the interview farmers.



4.3.2 The clover content of pastures

Based on their visual assessments, the farmers surveyed believed that white clover was their most dominant resident pasture legume (Figure 12). The visual observations ranged from a little over 20% in younger pastures (2 years old) to around 14% in older pastures (10 years) on both lucerne and no lucerne farms.

Figure 12: The changes in pasture clover cover over time for the surveyed farms.

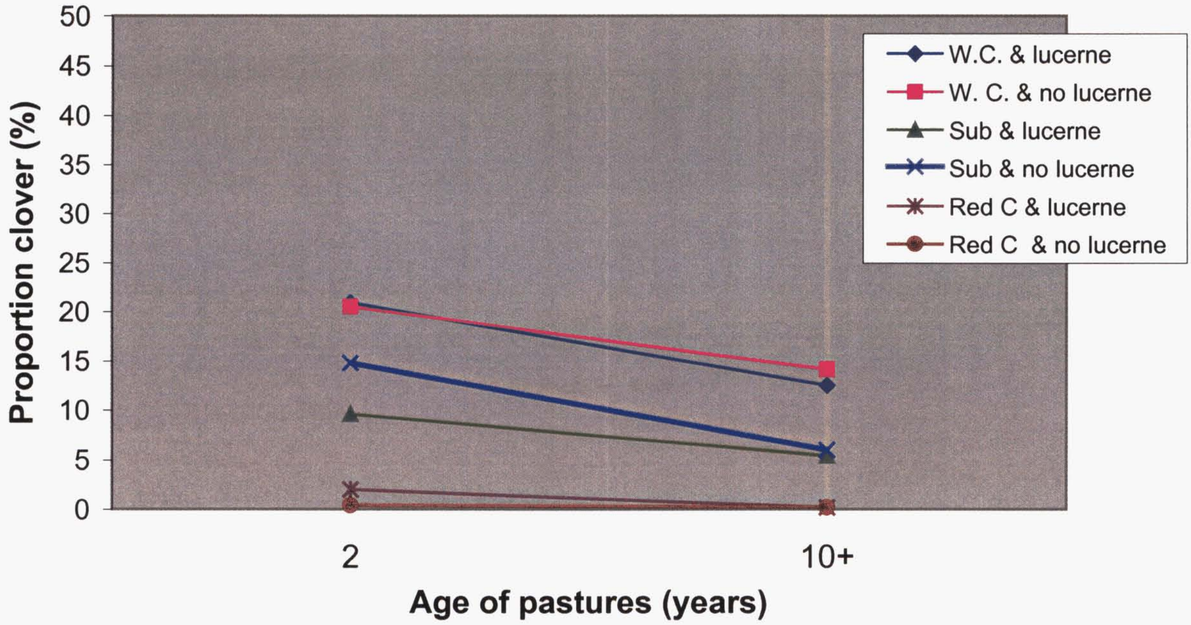
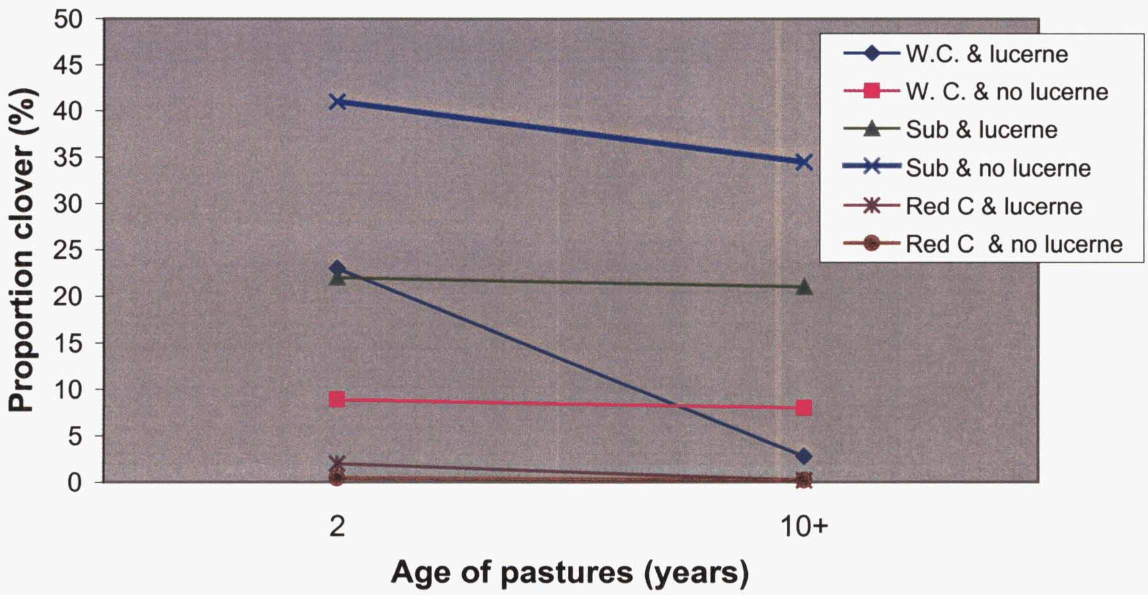


Figure 13: The changes in pasture clover cover over time on the interview farms.



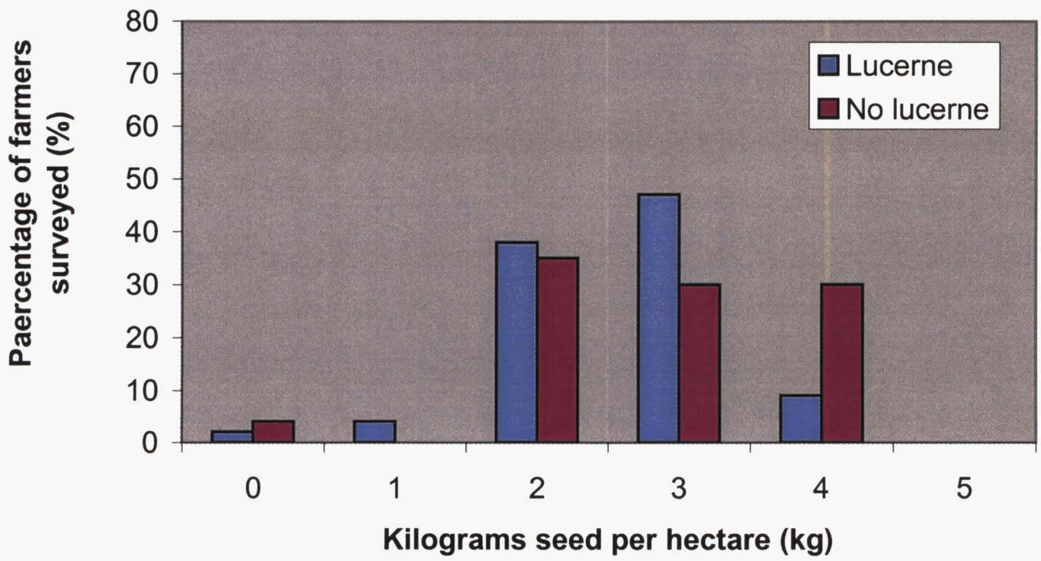
Sub clover levels were 10% in young pastures and declined to 5.% in older pastures on lucerne farms. On the 'no lucerne' farms the sub clover content was 15% in young and 6% in older pastures. The red clover contribution was less than 2% in young pastures and declined to less than 1% in the older pastures on both farm types.

On the 'interview farms', a more marked decline in the white clover content was noted, based on the author's observations. The white clover content was similar to the surveyed farms in young pastures at 23%, but was very low in older pastures at 3% on the interview lucerne farms (Figure 13). The white clover content in young pastures on 'no-lucerne' farms was 8.9% and declined to 8 % in older pastures. These interviewed farmers felt that white clover only persisted in their pastures for 4 years compared to 6 years estimated by the farmers in the survey. Red clover content was less than 2% on both properties in younger pastures and almost non-existent in older pastures. The sub clover content was estimated as 22% in young and 21% in older lucerne pastures, but was much higher on the no lucerne properties at 41% in young and 35% in older pastures.

4.3.3 Legumes sown in pasture mixes

White clover and red clover are the two legumes that are still sown in the greatest volumes on the farms surveyed. Where clovers were sown, the average sowing rate for the white, red and sub clovers were similar (2.35kg) (Figures 14, 15 and 16).

Figure 14: White clover seed sowing rate in pasture mixes on surveyed farms.



Almost all (97%) of the farmers surveyed sowed white clover in the pasture mixes, but 38% of those surveyed sowed red clover and 34% sowed sub clover for both the farming groups surveyed.

Figure 15: Red clover seed sowing in pasture mixes on surveyed farms.

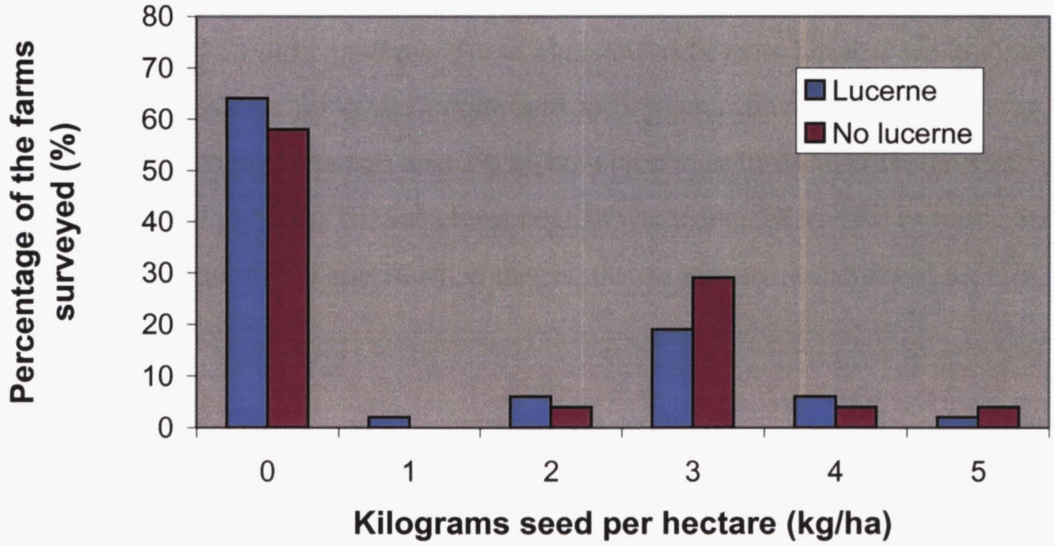
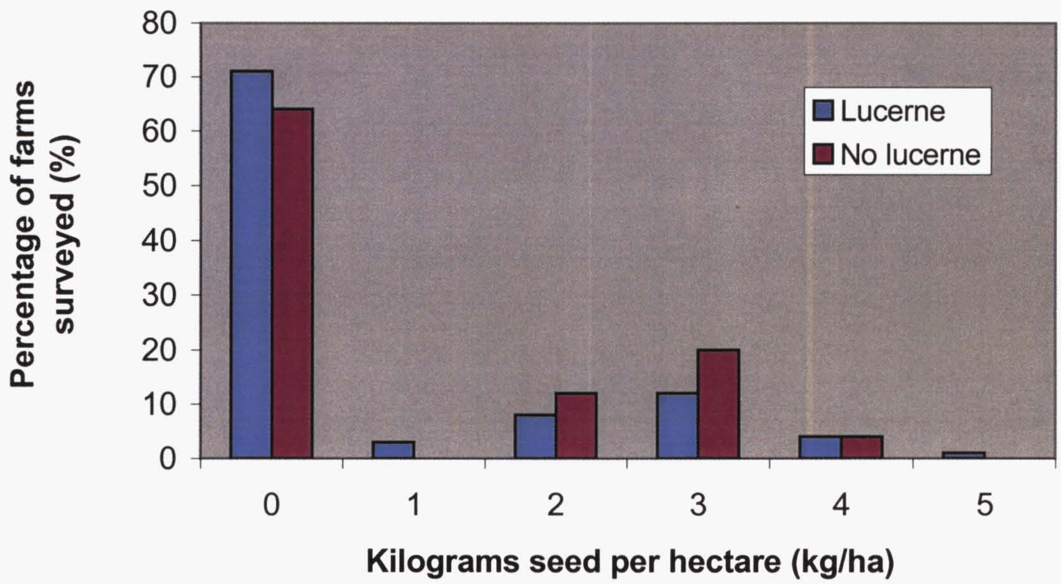


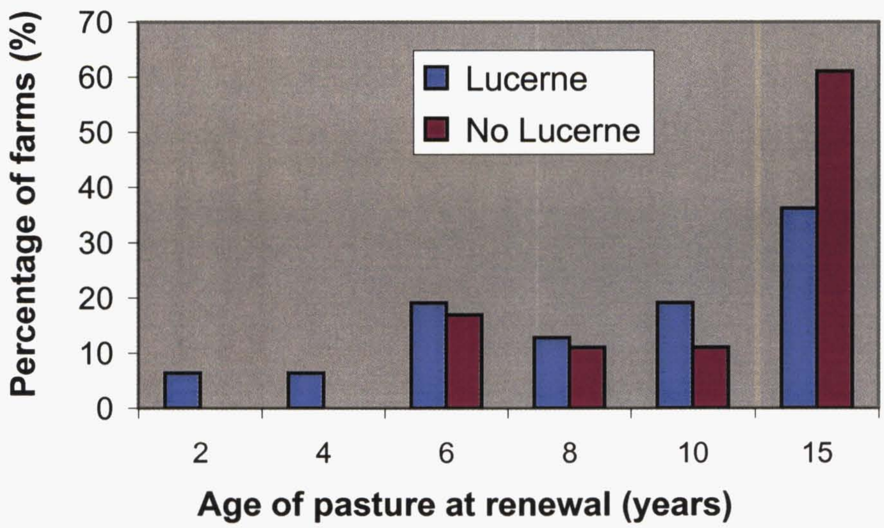
Figure 16: Sub clover seed sowing in pasture mixes on surveyed farms.



4.3.4 Age of pastures when renewed

The lucerne farmers surveyed renewed their pastures on average every 10 years and the no-lucerne farmers every 12 years (Figure 17).

Figure 17: The age of the pastures when renewed for the farms surveyed.



4.3.5. Cultivation methods adopted

The results of both the survey and the interviews indicated that many dryland farmers still plough rather than use surface working or direct drilling (Figures 18 and 19).

Figure 18: The preferred cultivation method for the lucerne and no-lucerne survey farms.

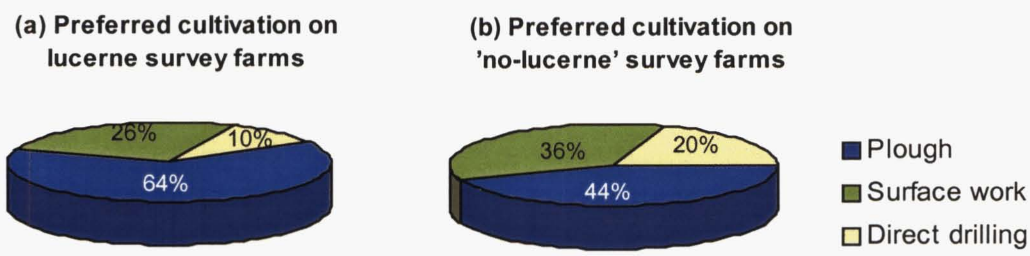
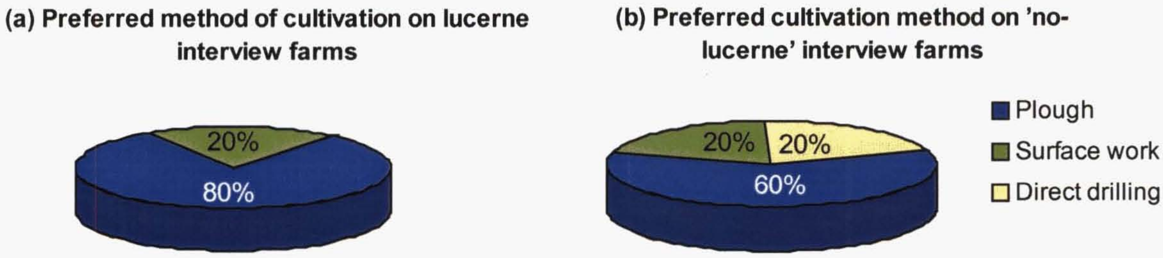


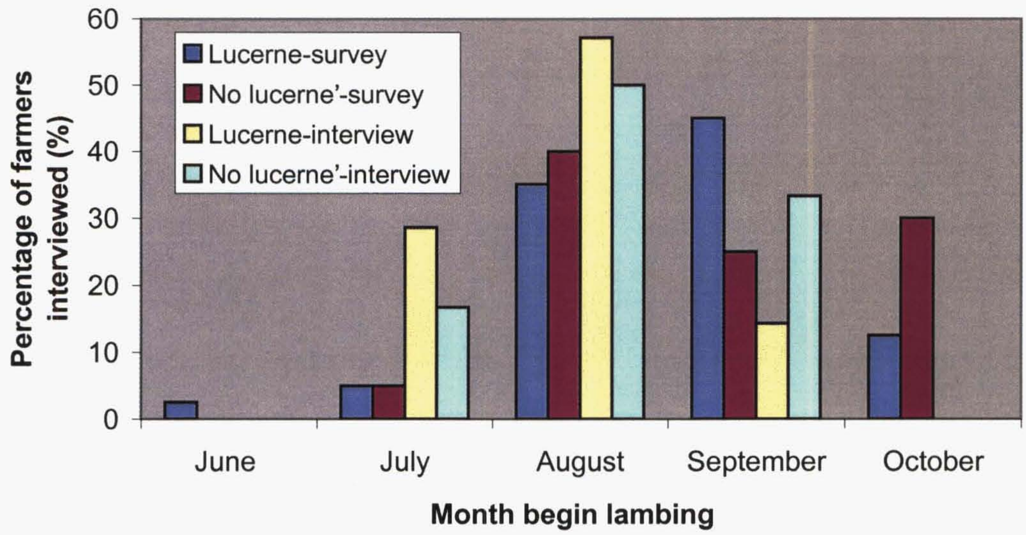
Figure 19: The preferred cultivation method for the lucerne and no-lucerne interview farms.



4.3.6 The timing of lambing

On average, the lucerne farmers from the survey farms lambed three weeks later (September 6th) than did the 'no-lucerne' farmers (August 19th) (Figure 20). Over 60% of the lucerne farmers surveyed had two lambing dates, with a smaller mob of ewes mated to a terminal sire lambing first and the main mob lambing six later on average on September 6th .

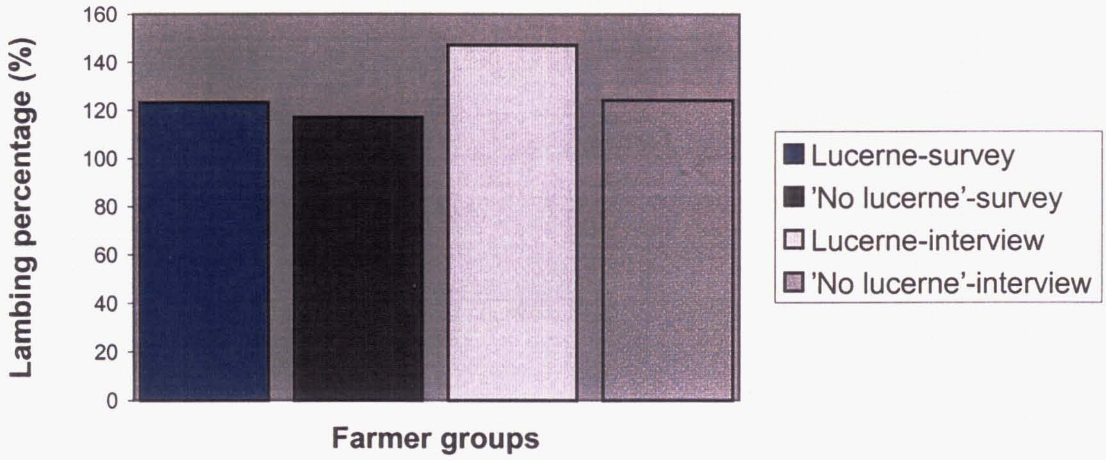
Figure 20: The timing of parturition on each of the 'survey' and 'interview' farms.



4.3.7 Lambing percentages

The lambing percentages (survival to tailing) were greater on all the lucerne farms compared to the no-lucerne properties. The differential was greater within the interview group, 147% lambing on lucerne and 124% on no-lucerne farms (Figure 21). The surveyed lucerne farmers lambing averaged 123% for lucerne and 117% for no lucerne (Figure 21).

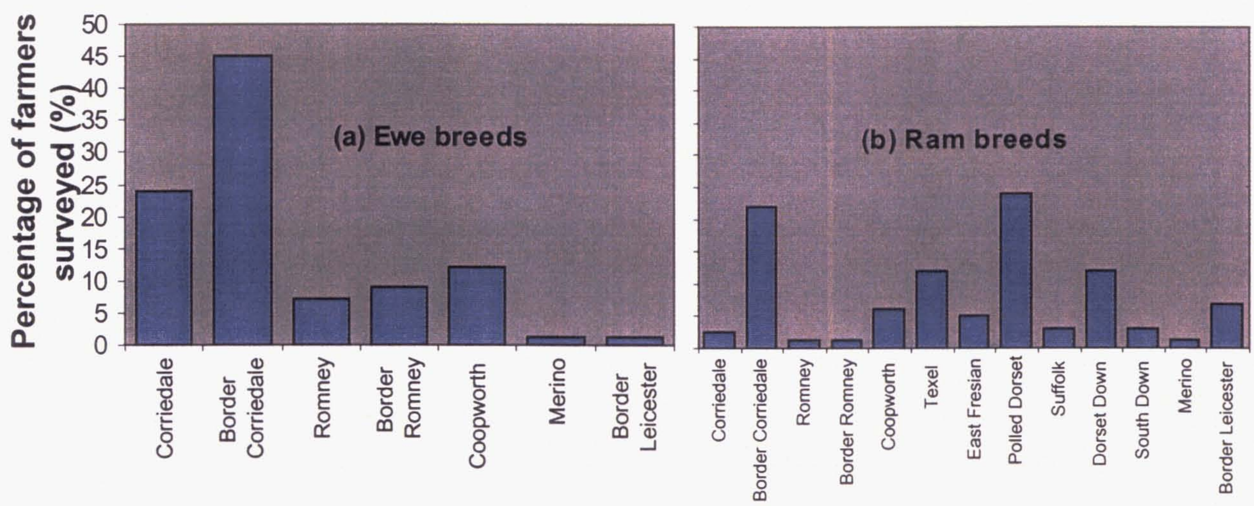
Figure 21: Lambing percentages on the survey and interview farms.



4.3.8 Ewe Breeds

Almost half of the farmers surveyed (45%) used Border Corriedale as their preferred ewe breed followed by Corriedale (24%), Coopworth (12%), Border Romney (9%) and (7%) Romney (Figure 22). The most common sires used on the farms surveyed were Polled Dorset (24%), Border Corriedales (22%), then Dorset Downs (12%) and Texel (12%) rams (Figure 22).

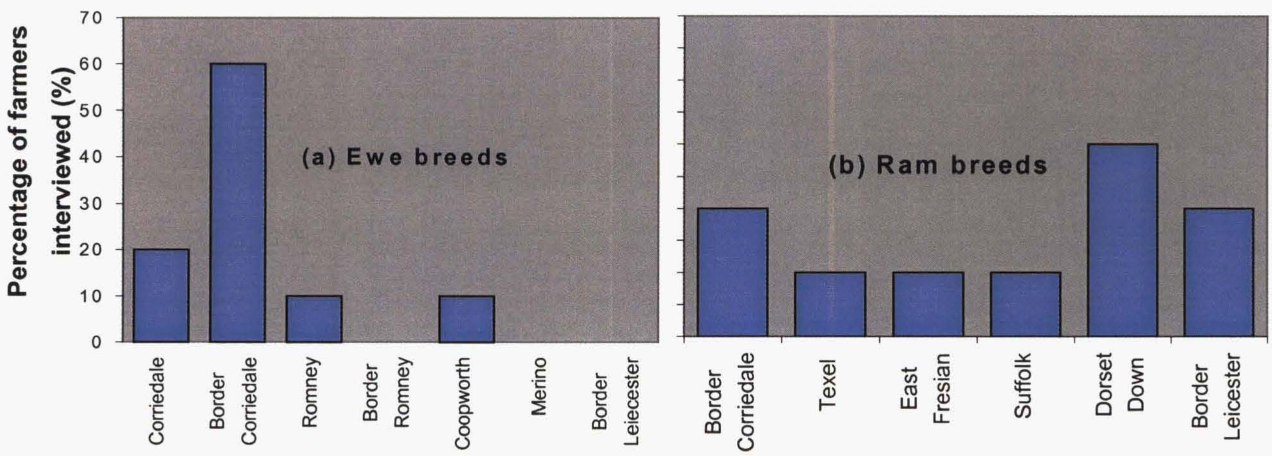
Figure 22: The ewe breeds and ram breeds used on the surveyed farms.



The predominant ewe breed on the 'interview' farms was the Border Corriedale (60%) followed by Corriedale (20%), Romney (10%) and Coopworth (10%).

The preferred ram breeds used on the interview farms were Dorset Down (30%), Border Corriedale (20%), Border Leicester (20%), Texel (10%), Suffolk (10%) and (10%) East Fresian (Figure 23).

Figure 23: The ewe breed and ram breeds used on the interview farms



4.3.9 Winter greenfeed crops sown

The survey showed that the percentage of the farm's area sown in greenfeed was less on the traditional sheep and beef farms surveyed compared to the sheep and beef farmers that winter grazed dairy cows or farmed deer). The sheep farmers surveyed who grazed dairy cows and/ or deer grew 18 hectares of winter greenfeed with the average or 10% of the total farm area (Figure 26). The traditional sheep and beef farmers grew 15 hectares of greenfeed on average or 8% of the total farm area (Figure 24).

Figure 24: The distribution of surveyed sheep and beef farms growing winter greenfeed (expressed as a percentage of each total farm area).

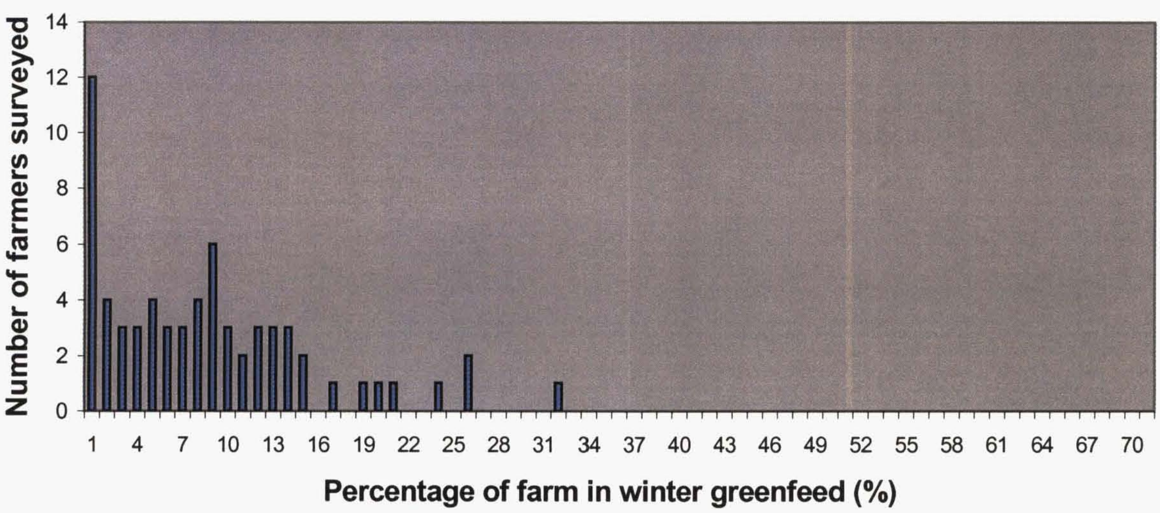
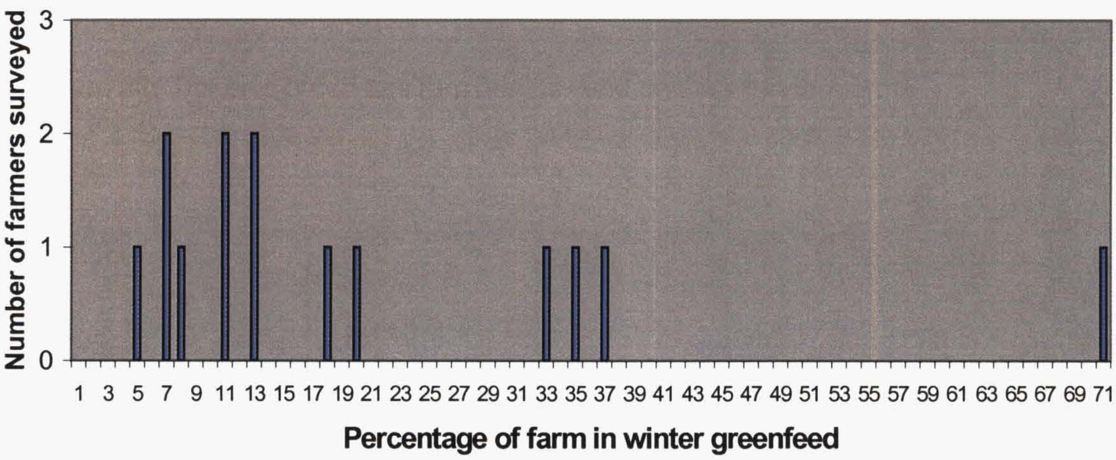


Figure 25: The distribution of surveyed sheep and beef farms growing winter greenfeed and grazing dairy cows and/or deer (expressed as a percentage of each total farm area).



The total winter greenfeed areas sown are greater (18 ha) for the surveyed sheep and beef farmers that are wintering dairy cows or grazing deer, compared to the traditional farmers sheep and beef only (15%) (Figures 26).

For both groups growing winter greenfeed, annual grass was the predominant feed sown (30 % for + dairy cows: 20% for - dairy cows), followed by rape turnips and turnips and grass varying between 14% and 18% of the types of greenfeeds sown (Figures 26 and Figure 27).

Figure 26: The area sown in winter greenfeeds per annum on sheep and beef farms surveyed that either (a) are not or (b) are grazing dairy cows and deer.

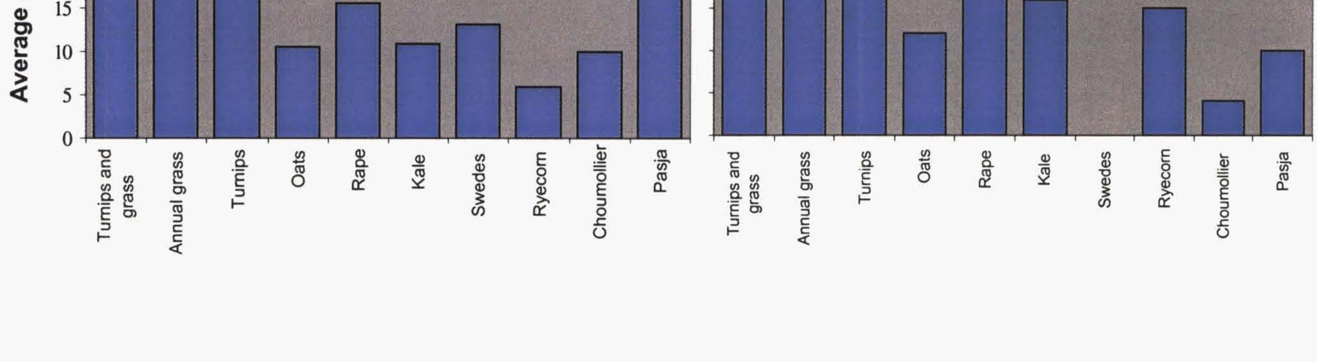
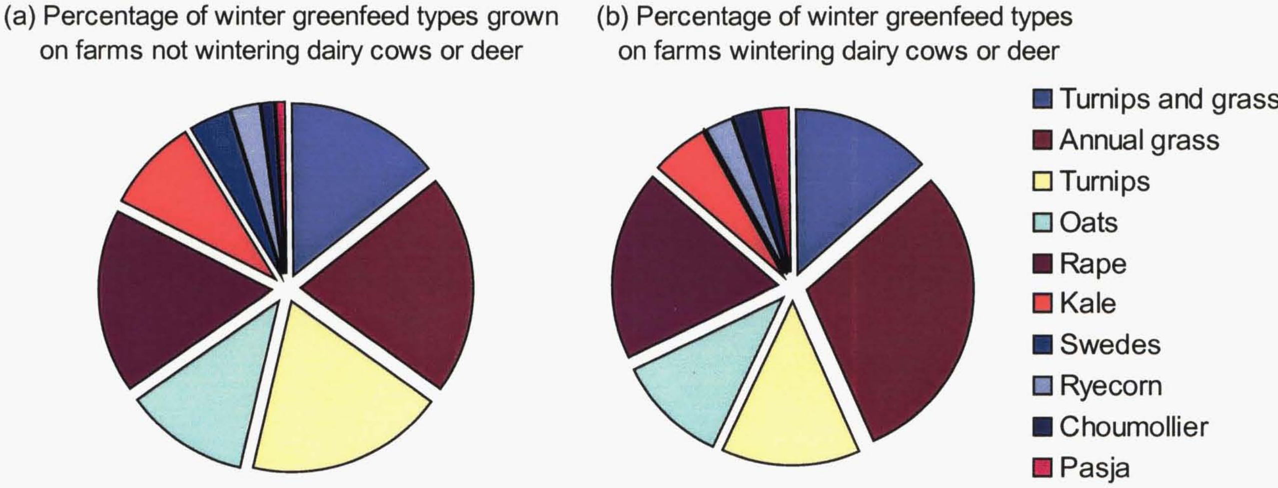


Figure 27: The winter greenfeed types sown expressed as a proportion of the total farm area sown in winter greenfeeds per annum.

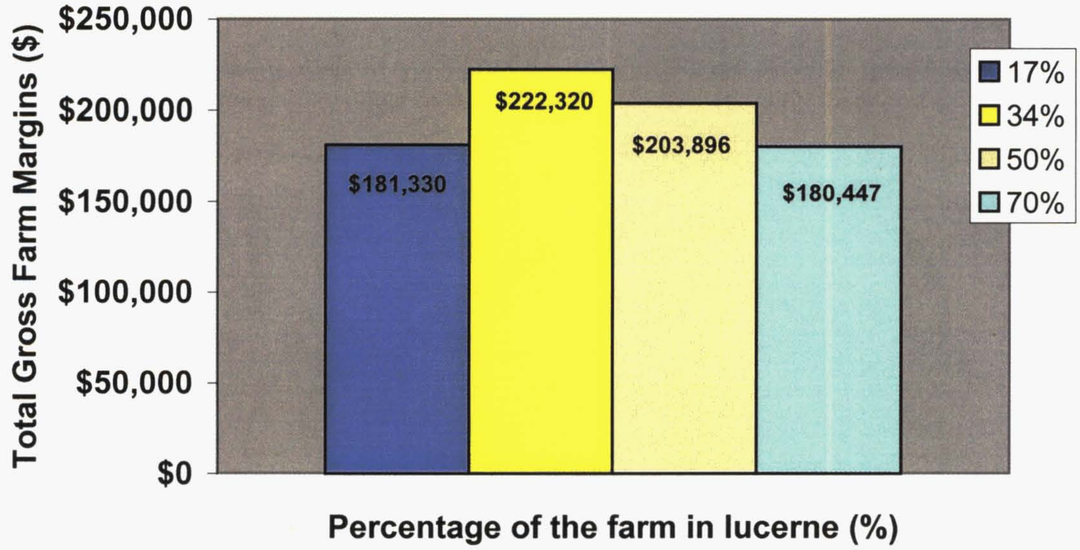


4.4 Linear Programme Results

The results from running the model showed that the cash and opportunity cost of winter feed exceeded that of any other time of the year for the data set used. For the analysis the model was constrained to grow 10% or more of winter greenfeed to allow for 10% pasture renewal each year. The model was very responsive to the ability of the system to feed stock over winter.

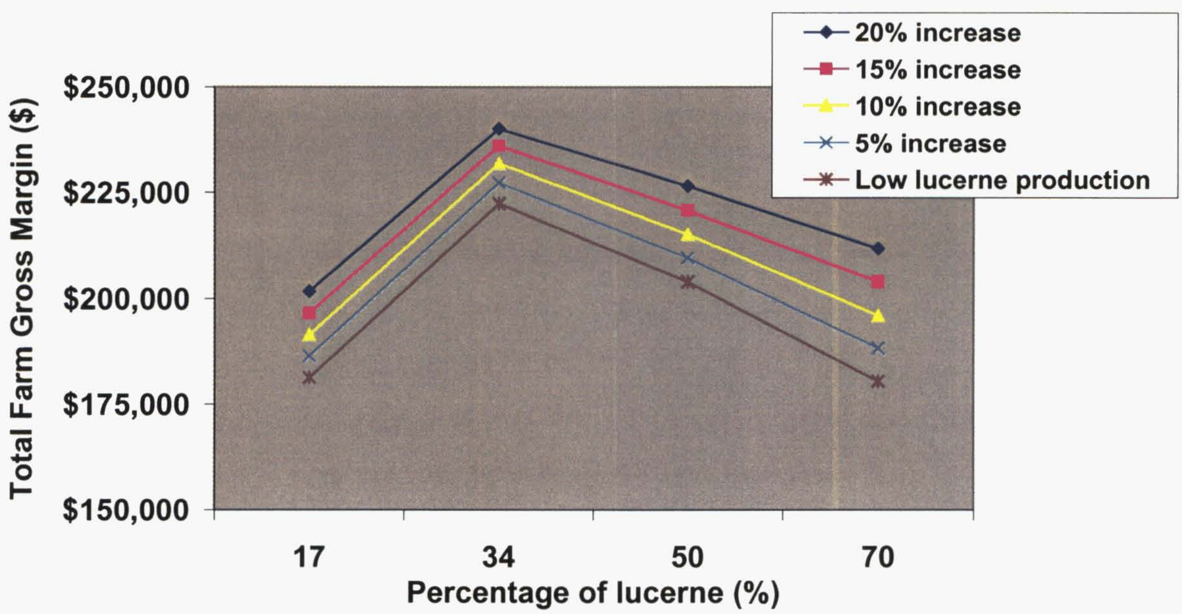
With sub clover based pastures available the model's optimal solution was to grow 34% of the farm in lucerne, 57% (226 hectares) in sub clover pastures, 10% in winter greenfeed and conserve 4915 conventional bales of lucerne hay. The model uses almost all of the available lucerne to feed stock over the warmer months, resulting in minimum conservation and uses sub clover based pastures to feed the animals for the rest of the year. The cash and opportunity cost of producing sub clover based pastures over the cooler season is less than the cost of growing more lucerne and conserving feed for winter supplements, hence the large area in sub clover pastures.

Figure 28: Total farm gross margin with increasing lucerne areas and sub clover pastures



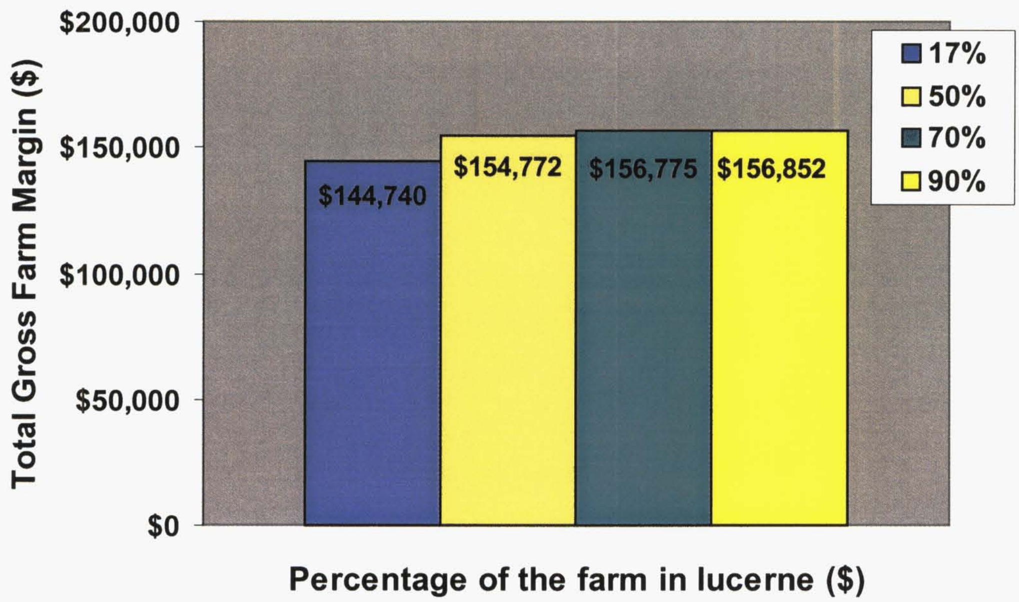
The lucerne growth rates were increased by 5, 10, 15 and 20% to carry out a sensitivity analysis with less conservative growth rates (Figure 29).

Figure 29: Changes in total farm gross margin with increased lucerne production and areas plus sub clover pastures



The same model was run a second time, but without the sub clover pastures and the results were significantly different. The model was still constrained to grow 10% of winter greenfeed or more. The optimal farm gross margin was maximised at $156,800 by increasing the lucerne area to 90% of the total farm area, growing 10% greenfeed and conserving 45,200 bales of hay for the winter feed shortfall. This represented a $12,100 increase in the total farm gross margin when compared to the $144,700 gross farm income resulting from growing 17% in lucerne. The cash value and opportunity cost of growing excess feed over summer and of conserving as hay, was less than the cost of wintering on ryegrass white clover pastures or greenfeed. Hence the optimum solution determined by the model was to grow 90% of the farm in lucerne (Figure 30).

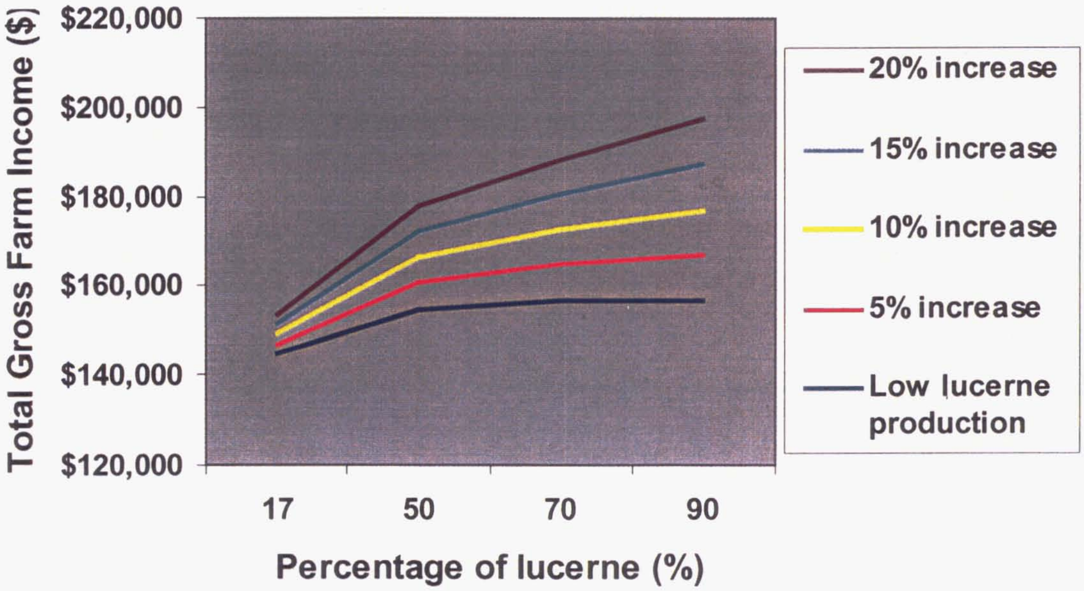
Figure 30: Total farm gross margin with increased lucerne areas and white clover plus ryegrass pastures, but no sub clover pastures



The results from these two analyses show that the cool season sub clover production is very valuable to these dryland systems. Yet the survey results show that 71% of the lucerne farmers and 64% of the pasture only farmers did not sow sub clover seed in their pasture mixes. If lucerne farmers doubled their area of 17% to 34% the model predicts that the resulting farm gross margin would increase by $40,990 (from $181,330 to $222,320) - provided they sowed subclover in their pastures at the recommended rates (Figure 28). For farms with no subclover pastures the total farm gross margin is shown in Figure 30.

The lucerne growth rates were again increased by 5, 10, 15 or 20% respectively, to carry out a sensitivity analysis.

Figure 31: Changes in total farm gross margin with increased lucerne production and areas but no sub clover pastures.



Chapter 5 Discussion

5.1 Confirmation of hypothesis

The pasture legume content in drought prone dryland properties is very low. The predominant pasture mix sown on dryland farms continues to be ryegrass and white clover, although white clover does not persist in drought conditions. Farmers have been reluctant to sow alternative legume species despite some obvious production advantages and so the current area of lucerne grown on farms appears to be small. Dryland farmers with sub clover seed stocks in the soils are aware of the cool season production gained from having sub clover within their pastures, but are not including it within the pasture mixes that they currently sow.

The survey results confirm the hypothesis of this study and the current literature. White clover is the most commonly sown clover variety, but it fails to persist and so the legume content in older pastures is low. The white clover content in ryegrass/white clover pastures was visually assessed by the farm owners as approximately 20% in younger pastures and less than 15% in older pastures (of 10 years old or more). For the farms growing lucerne, the total area sown averaged 17% of the total farm area, with the largest area being 30% (on one farm only). The surveyed farmers believed that white clover persisted in their pastures for 6 years on average but the farmers with no lucerne renewed their pastures every 12 years and those with lucerne every 10 years.

The majority of farmers with sub clover in their pastures are relying on the hard seed stocks in the soil from successive populations of sub clover seed were first sown in the 1950's or earlier. Most believe that sub clover persists indefinetly and so few are actually sowing sub clover. Several farmers commented on the fact that sub clover used to be prolific on their properties and now it is far less dominant. The literature indicates that sub clover seed stocks in the soil decline over time due to insect and microbial predation, false strikes as well as adverse management practices such as ploughing, herbicide usage and poor grazing management particularly in Autumn after the sub clover seedlings have germinated. Therefore the assumption by farmers that sub clover lasts indefinetly is incorrect and if sub clover seed is not sown in pasture mixes then the contribution of sub clover to the annual pasture production will decline further.

5.2 Area of surveyed farms in lucerne

One of the initial objectives of this study was to compare the management of farms with 50% or more of lucerne to farms reliant on pasture only and with over 50% of their property in sub clover based pastures. The majority of the names of the farmers surveyed were obtained from the attendance records of a series of seminars on lucerne production throughout Canterbury, Otago and other South Island districts. Despite this fact the survey respondents generally grew little or no lucerne with the average being 17% on the farms that did grow lucerne with the largest having only 30% of his farm in lucerne (Figure 7). As lucerne requires different management compared to traditional ryegrass/white clover pasture, if a farm has a large proportion of its total area in lucerne the overall farm management differs to farms with little or no lucerne. With only 17% of the property on average in lucerne, it will have less of an impact on the overall farm management than if up to 50% or more was grown.

In 1981, Canterbury was the region of New Zealand where the greatest area of lucerne was grown (Department of Statistics, 1981). If the farmers surveyed are representative of all the dryland farmers in Canterbury then the area of lucerne grown specifically for grazing is currently very low compared to that grown in the early 1980's (Wynn-Williams, 1982). Almost all of the farms surveyed are technically capable of growing lucerne well. Farmers appear to have lost confidence in lucerne due to the pest and disease problems of the 1980's. Since then pest and disease resistant varieties have been developed, but farmers have been reluctant to put too much reliance on lucerne despite the obvious production advantages (Langer, 1990). Lucerne also has the added advantage of being grass grub resistant once established (East *et al.*, 1980; Wynn-Williams, 1982). Grass grub can cause significant pasture production losses in dryland pastures.

During the 1970's and early 1980's 'Wairau' was one of the most commonly grown lucerne cultivars. However, it proved to be one of the most susceptible to new pests and diseases that arrived during that period. The survey results show that 32% of farmers still sow 'Wairau' lucerne, with the more resistant cultivars only sown by a smaller number of farmers. Otaio and Renegade were both sown by 16% of the farmers, AS13R by 12% and Pioneer WL 5454 by 9%. These newer cultivars have greater productivity and longevity when faced with insect or disease challenge, so farmers could increase the overall dry matter and persistence from the lucerne component of their pastures by sowing new the improved cultivars. Purves and Wynn Williams (1994) produced a list of pest and disease resistant varieties (Table 7).

Table 7: The pest and disease resistance of lucerne cultivars curren... New Zealand (Source: AgFACT no:201, September 1997).

Lucerne cultivars available in New Zealand									
		Pest and Disease Resistance							
Cultivar	**Dormancy**	**BGA**	**PA**	**SAA**	**BW**	**SN**	**PRR**	**VW**	**LD**
Wairau	SD	S	S	S	S	S	S	S	S
G. Otaio	I	R	R	R	R	R	R	R	R
G. Kaituna	I	R	R	R	R	R	R	MR	MR
WL 320*	SD	R	R	R	R	S	S	MR	MR
WL 322HQ	SD	MR	R	R	R	MR	R	LR	-
WL 323	SD	-	R	MR	R	R	R	R	R
AS 13R	A	S	SR	R	R	R	R	S	S
Pioneer 5444	SD	S	MR	R	MR	SR	SR	R	-
Pioneer 5454	SD	MR	R	R	R	MR	R	MR	-
Pioneer 5717	A	R	R	R	SR	SR	R	SR	-
Renegade	D	-	R	R	R	0	R	SR	-
Runner	D	-	S	S	R	SR	S	S	-
Washoe*	SD	S	MR	R	R	R	R	S	S

<u>**Key to table:**</u>

* becoming unobtainable

Pests and Diseases :

BGA = Blue-green aphid, PA = Pea aphid, SAA = Spotted alfalfa aphid, BW = Bacterial wilt, SN = Stem nematode, PRR = Phytophthora root-rot, *VW = Verticilluim wilt, LD = Leaf diseases*

Levels of resistance :

R = Resistant, MR = Moderately resistant, SR = slightly resistant, S = Susceptible, - = No information.

When faced with diminishing real returns for produce farmers must increase the production per unit of land to remain viable in the industry. Historically, the greatest lamb returns came from having prime lambs available in early spring to be exported the U.K to meet the shortfall in supply in the U.K market place. This suited the Canterbury dryland sheep farmer who lambed early (late July to early August) and sold as many lambs as possible by late November, before drought conditions set in. However, the pricing structure for lambs has changed now in New Zealand, with more diversified markets and premiums paid throughout the year for export grade lambs. This means that if dryland sheep farmers placed a greater reliance on lucerne to finish lambs they would not be penalised by lambing later. Growing lucerne allows the farmer the flexibility to finish lambs over late spring/ summer, to increase the liveweight gains from lambs due to the extra protein supply and digestibility of lucerne, and can potentially increase the lambing percentage through increased ewe nutrition. In drought-prone areas lucerne is still capable of producing at least 50% more production than traditional ryegrass/white clover, across a range of soil types and at very little additional cost (Appendix 3). McCleod (1976) showed that lucerne production exceeded that of ryegrass and white clover by 78% in years of extreme drought. To achieve the maximum pasture production from dryland farms 50% lucerne should be grown, with 40% ryegrass/sub clover pastures and 10% greenfeed. With 10% of the property in greenfeed this should be sufficient to provide the main ewe mob with 4-6 weeks feeding, depending on the autumn rains. If the greenfeed grazing begins in early July the sub clover pastures could be spelled for up to 6 weeks when the sub clover production is beginning to accelerate. When the greenfeed grazing is finished in mid August ewes can begin grazing the sub clover dominant pastures for the next 4-5 weeks until the lucerne is available for grazing. The improved nutrition and higher protein forage resulting from the sub clover will help reduce the metabolic disorders in ewes carrying multiple lambs. Lambing could commence on pastures but ewes and lambs should be transferred onto lucerne in the last week of September and remain there until the lambs are finished. Lucerne should be used as a fresh forage firstly and conserved only if feed supply exceeds the animal demand. The sub clover based pastures could be used for feed conservation as long as seed set is not compromised. By growing 50% lucerne the stock will be better fed and the need for conserved feed will be reduced provided the overall pasture management is good.

The soil pH ranged from 5.4 to 6.6 for the paddocks growing lucerne on the surveyed farms, with pH 6.14 being the average. White (1970) showed that productivity significantly increased at pH 6.5 when compared to production at pH 5.6 to 5.9. The farmers growing lucerne could further improve the annual production from their lucerne by the application of more lime to maintain the soil pH at 6.5 or greater. Of the farmers surveyed 25% had a pH of 5.9 or below, 64% ranged from 6.0 to 6.4 with only 11% having their soil pH in the optimum range for lucerne production of 6.5 or greater (Figure 10).

5.3 The clover content of pastures

Surveyed lucerne farmers visually assessed (Table 5) the white clover cover of their pastures as 20.9% in young pastures declining to 12.5% in older pastures (Figure 12). The 'no lucerne' surveyed farmers recorded similar levels. The white clover cover was visually assessed as being (23%) on average in young pastures on the interviewed lucerne farms (Table 6), which rapidly declines to 2.8% in older pastures (Figure 13). This rapid decline may be due to white clover perishing during drought conditions. The white clover cover on non-lucerne farms is relatively low remaining close to 10% of the pasture composition. White clover persistence declines in drought conditions (Hoglund, 1990; Fraser and Keoghan, 1992) whereas sub clover is able to persist as long as autumn rains occur (Calder, 1951; Langer 1982). In dry conditions white clover acts as an annual and is less competitive than sub clover due to its small seed size, which is 10% of the size of sub clover seed (Dear and Sandral, 1997).

The differences in the persistence of white clover between the surveyed and interviewed groups may be due to the difference in the soil types the two sample groups are farming. The interview group all farmed on light free-draining soils with the exception of one (10%) that farmed 1,000 hectares of clay downs with an annual rainfall of 1,000 mm. Up to 35% of the farmers surveyed had a range of soil types including some heavier land on their properties. The increased water holding capacity of these heavier soils may have allowed greater annual white clover productivity and persistence. The details regarding clover contents contained in the surveys are visual estimates made by the individual farmer, whereas the clover details in the interview data are also a result of visual estimates taken by the author. Some of the discrepancy between the groups may also be explained by differences in the actual visual estimates between farmers and the author. It is very difficult to visually estimate pasture composition with any degree of accuracy. The estimates for clover content, as a percentage of pasture cover, tend to be over-estimated because of the large leaf surface area of clovers compared to the prostrate leaf of the grasses. The farmers' visual estimates and the estimates of the author were probably greater than the actual proportion of clover dry matter, as a fraction of the total pasture mass, that existed in the pastures when assessed. Although most farmers were capable of recognising that clover exists in the sward, some were unable to positively identify the clover species or to accurately estimate the clover content of their pastures.

White clover and red clover are the two legumes that are still sown in the greatest volumes on the farms surveyed (Figure 14 and Figure 15). The white clover content in the young pastures was not very high at approximately 20% and declined to nearer 14% in older pastures, resulting in poor pasture quality. Most of these dryland farms derive the majority of their income from sheep and rely on good quality spring pastures to be able to finish lambs prior to the onset of drought.

On the interview farms (n =10), a different pattern of clover contents emerged as compared to the 'surveyed farms' (Figures 12 and 13). The sub clover content decreased slightly over time from 22% to 21% on the lucerne farms interviewed and from 41% to 35% on the no lucerne properties. There appears to be a higher sub clover content on the no lucerne farms (n =5) and they have up to 20% more sub clover on average than the lucerne farms (n =5). This may be partly explained by the farm management practices adopted on each of the farm types. For example, lucerne farmers periodically spray with hormonal herbicides (such as Centurion Plus, Targa, Gallant, MCPA, Dicamba, Paraquat and Atrazine or mixes of each) that can severely reduce the seed set of sub clover (Gregan, 1982). Sub clover needs to set more than 600 kg/ha of seed per year and able to maintain high cool-season activity to ensure its persistence. Grazing management may also influence the sub clover levels. Many lucerne farmers use rotational grazing with their animals, whereas the non-lucerne farmers may not. Sub clover production and persistence is enhanced by set stocking (Chapman *et al.* 1986), while rotational grazing on lucerne properties may result in sub clover production being depressed due to shading.

Sixty percent of the lucerne farmers sow no sub clover at all, despite the fact that they perceive it to contribute to 20% of their pasture composition (Figure 16). Of the 'no lucerne' farmers interviewed, 40% sowed no sub clover, 40% sowed two kilograms per hectare and one sowed 3 kg/ha. The current recommended sub clover sowing rate is 6-10 kg/ha, with the companion grass sown at less than 20kg/ha to ensure good sub clover persistence and productivity. By not sowing sub clover these dryland farmers are relying on the available sub clover hardseed that exists in the soil. Sub clover seed has a hard outer coating that is impermeable to water. Even in favourable germination conditions only a small portion of the soil seed stocks will germinate, leaving the high seed numbers in the soil in case germination mortalities occur (Loftus Hills, 1944). The impermeability of these seeds reduces over time and so the soil seed stocks will become depleted by microbial and insect predation, decay and poor autumn germination conditions, resulting in false strikes. Many of the farmers interviewed and most of those from the survey who had sub clover based pastures, believed that sub clover lasts in their pastures indefinetly. However this is not correct (Smethan and WuYing, 1991) with most volunteer sub clover germination coming from seed set up to 3-4 years previously. Unless pasture management and cultivation techniques favour sub clover germination and seed set, the soil seed stocks will decline over time. Deep burial of sub clover seed by ploughing will also result in declining pasture contents. Only a very small portion of seeds remaining will germinate after 20 years or more in the soil (Smetham and Wu Ying, 1991). Sub clover has a major contribution to the pasture productivity on these interview farms but the majority of the farmers are not sowing it in their seed mixes.

With the low clover content in their pastures, particularly the older pastures the farmers surveyed would be better to renew pastures more often to maintain the white clover content and improve the pasture quality. The lucerne farmers surveyed renewed their pastures on average every 9.9 years and the no-lucerne farmers 12.2 years (Figure 17). Another alternative to more regular pasture renewal maybe to oversow more clover into established pastures or to include the more persistent sub clover in the pasture sowing mixes. Sub clover has the ability to persist if managed well and is capable of providing high quality feed in the late winter and spring seasons. The newer late flowering Sardinian sub clover ecotype cultivars such as 'Goulburn', 'Denmark' and 'Leura' have no oestrogen problems plus have increased production and palatability compared with the older 'Tallerook' and 'Mt Barker' seed stocks that exist on many of the surveyed farms.

Ewes require high protein intake over the early lactation period to minimise the post-parturient breakdown in their natural resistance to intestinal parasites (Donaldson, 1999). Sub clover maybe able to fulfil this requirement. Ewes suffering from a breakdown in their natural resistance, due to poor nutrition over lambing, provide the greatest source of pasture contamination. With young naïve lambs being the most susceptible to production losses caused by intestinal parasite damage the cost of poor ewe nutrition is greater than many farmers realise.

5.4 Preferred cultivation method

Most of these dryland farms are on lighter soil types that have a low water holding capacity and high proportion of stones in the topsoil. The use of minimum tillage and direct drilling, in conjunction with spraying if necessary, for pasture renewal is the best method to ensure maximum moisture retention and minimum stone disruption (Baker *et al.*, 1990; 1996). Adequate soil moisture is essential for seedling germination so farmers, especially in drought prone regions should adopt cultivation methods to minimise moisture losses.

Of the lucerne farmers surveyed, 64% ploughed, 26% surface worked and 10% used direct drilled (Figure 18). For the no lucerne farmers surveyed 44% ploughed, 36% surface worked and only 20% direct drilled (Figure 19). With better sprays and the advanced machinery technology for direct drilling now available, it is surprising that more farmers are not using minimum cultivation techniques. Many farmers were put off direct drilling in the 1970's and 80's due to poor germination rates due to the drills not being as technically advanced as they are today. The bad publicity direct drilling received two decades earlier still lingers amongst the farmers surveyed, who still mostly prefer to plough.

5.5 Timing of lambing

On average the lucerne farmers from the survey lambed three weeks later (September 6th) than did the 'no-lucerne' farmers (August 19th) (Figure 20). Over 60% of the lucerne farmers surveyed had two lambing dates, with a smaller mob of ewes mated to a terminal sire lambing first and the main mob lambing six later on average on September 6th. The results from the current survey suggest that lucerne farmers lamb on pasture, graze lucerne in early September, then use their lucerne for at least one cut of either hay or silage. The greatest grazing pressure is during the early lambing period prior to late September when lucerne grazing can commence. To achieve maximum spring production from lucerne, grazing should not commence before the last week of September when the plants internodes have fully elongated (Dunne *et al.*, 1999). By grazing lucerne in early September with ewes and lambs the spring lucerne production will be compromised by the animals removing the lucerne growth points, which are located at the top of the plant. Once these growth points are removed the plant will not grow until it has been fully defoliated by hard grazing or cutting. This means that even small lambing mobs browsing in a large lucerne paddock can cause significant reductions to the subsequent lucerne spring production. The early lambing mobs on these lucerne farms are generally cull ewes that are mated to a terminal sire, with the resulting progeny destined to be finished then slaughtered. If these farmers increased their area of lucerne they could lamb these ewes later and graze them on lucerne only to maximise the lamb growth rates and reduce the time taken to finish the lambs. By grazing early, old ewes are eating some of the most valuable late winter feed that could otherwise be used to build up the condition on the main lambing mob prior to parturition.

With similar prices paid for lambs throughout the production season farmers would be well advised to sow more lucerne. The annual maintenance cost difference between lucerne and pasture is small (Appendix 3), but lucerne is capable of producing over 50% more feed annually (particularly where rainfall is less than 600mm) and of a higher quality than traditional pastures. Dryland farmers could maximise their stock carrying capacity and performance by growing up to 50% lucerne on their properties and begin lambing in early-mid September on pasture for a week or two prior to grazing the lucerne. The linear programme results showed that the total farm gross margin would be maximised when up to 34% of dryland farms are in lucerne, 56% in sub clover and 10% in greenfeed. The survey data shows that the farmers who grow lucerne, only grow relatively small areas (17% on average) and use it for conservation rather than fresh forage. The loss of nutritional value by conservation is high and so farmers would be best to use lucerne as fresh animal forage only. By growing a larger area in lucerne, the protein supply to ewes would be greater over the summer period. This would result in heavier liveweight ewes, higher lambing percentages (Jagusch *et al.*, 1982) and less need for conserved feed. The increased protein supply and increased light penetration due to the upright growth habit of lucerne results in lower intestinal worm burdens, which generally means increased animal performance (Waghorn *et al.*, 1987; 1994). On intensive lucerne growing farms, with the residual remaining grass/white clover pasture paddocks being used primarily for winter grazing, the cool season pasture supply would be further enhanced by sowing modern cultivars of sub clover, if it is well managed and sown at the recommended seeding rate.

The majority of farmers in both groups, the survey and interview groups, sow winter greenfeed and graze this in late winter to spell their permanent pastures. The most common lambing management adopted is set stocking on pasture over lambing, followed by an increase in ewes and lamb mob size as the lambs get older and rotational grazing on grass/white clover pastures or lucerne if available. This set stocking over lambing in the late winter/early spring is ideal for sub clover production, provided the animals do not graze the branching runners of the early flowering sub clover cultivars (Rossiter, 1978). Later flowering varieties do not develop runners until October, so are less prone to damage, but as their growth starts later in spring, and so a balance of varieties is advisable to ensure seed set.

5.6 Lambing Percentage

The lambing percentages (survival to tailing) were greater on all the lucerne farms compared to the 'no-lucerne' properties (Figure 21). The difference was greater within the interview group, 146.6% lambing on lucerne and 123.6% on no-lucerne farms. The surveyed lucerne farmers averaged 123.2% and no-lucerne 116.9%. The differences in lambing percentage between the interview groups and the survey comes from the pre-selection of the interview group, which had a high reliance on either lucerne, or sub clover.

The increased lambing percentage on lucerne farms may be attributed to better nutrition for ewes over the summer period. Many of the dryland farmers surveyed indicated that they often have little quality feed in autumn to flush their ewes. Some of the lambing increase on lucerne farms will be a result of increased nutrition and protein supply over mating resulting in increased ewe ovulation rates and lower embryonic moralities. If managed correctly lucerne guarantees good flushing feed, which is often lacking during drought years on properties with 'no lucerne'. Due to the deep taproot of lucerne, it is able to extract moisture and nutrients from deep within the soil profile that other shallow rooted plants cannot. This is why lucerne is capable of supplying high quality feed over summer and autumn for finishing lambs and feeding ewes at a time when many other traditional grass/clover pasture species have little or no productivity.

The survey results showed that those farmers growing lucerne achieved an average 20% increase in lambing, despite the average area of lucerne only covering 17% of the farm. If farmers were prepared to extend this to sowing 50% of the property in lucerne the lambing percentages could be greater still and their summer stock carrying capacity may also be greatly increased. The main emphasis on dryland sheep farms today is lamb production, therefore the increased lambing percentage and farm stock carrying capacity resulting from growing lucerne makes it difficult to see why more farmers do not grow lucerne. Technically, most of the surveyed farms could grow lucerne, but farmers appear to be reluctant to accept the management changes that may result. Financially there is a small additional annual maintenance cost from growing lucerne compared with traditional pastures. However, this cost is small when compared to the potential of having a reliable summer feed source, an increased lambing percentage or summer stock carrying capacity resulting from 50% or more of pasture growth annually. The reason why farmers are not sowing more lucerne is unclear. It would appear that since the decline in the 1980's due to pest and disease problems, farmers were forced to rely on ryegrass and white as an alternative feed source. Now new pest and disease resistant varieties of lucerne have been developed but farmers are reluctant to change pasture species due to the management changes required and a lack of confidence in lucerne resulting from the problems of the 1980's.

The rotational grazing with a 42 day grazing interval and ten day grazing duration recommended by White (1982) is essential to achieve the maximum productivity and persistence out of lucerne crops. This generally requires larger mob sizes or smaller paddock subdivision by permanent or temporary fencing. Farmers appear reluctant to accept the extra management burden that lucerne requires despite the additional feed, lambing percentage increases and improvement in animal liveweight gains that may result from increasing the lucerne area grown. Instead farmers rely ryegrass/white clover pastures which have the advantage of being able to recover when badly mis-managed, yet have limited productivity and quality during dry, warmer months.

The 'no lucerne' surveyed farmers averaged 116% lambing compared with the no lucerne interviewed farmers 123%. The difference in lambing percentages may be attributed to the increased sub clover content in the pastures of the interview farms (Figures 12 and 13) providing increased pasture production for animal nutrition in the spring, prior to the onset of drought. With the regularity of drought on these farms the white clover production is limited and an increased sub clover content is likely to result in an increase in annual pasture supply. Sub clover is active during the cool season when soil moisture does not limit plant production. The nitrogen fixation from sub clover will also enhance the production of companion grasses. White clover is capable of doing the same over the summer months when the soil temperature is high and moisture is not limiting, but these conditions seldom prevail over summer on light land properties in Canterbury and North Otago.

5.7 Ewe breeds

The emphasis of sheep farmers has moved from wool production to increased lamb production. Historically many of the dryland farms surveyed ran Corriedale or half-bred ewes for both meat and wool production. With the recent depressed wool prices and increased lamb values these dryland farmers have either changed their breed types to a more dual purpose breed, or increased the use of terminal sires at mating. The change of emphasis to lamb production is evident from the ram breed choice used on the interview farms, where specialist terminal sires such as Dorset Down and Suffolk rams are used, along with the more dual purpose breeds of Border Corriedale and Border Leicester (Figure 23). The cross bred lambs produced by these sires have high hybrid vigour and are capable of producing high liveweight gains provided they are fed well. Almost half of the farmers surveyed (45%) used Border Corriedale as their preferred ewe breed followed by Corriedale, Coopworth (12%), Border Romney and Romney (Figures 22). The most common sires used on the farms surveyed were Polled Dorset, Border Corriedales, then Dorset Downs and Texel rams (Figure 22). The growth rates of the crossbred lambs would be greatly increased if lucerne farmers grew more lucerne, lambed later and if the lambs grazed lucerne only. If the farm expenses are similar each month and the pasture growth peaks in spring, then spring feed is the cheapest to produce. By growing lucerne, the production may be up to 3 times that of pasture in late spring, making it even cheaper per unit of dry matter. By lambing all ewes in late September all crossbred lambs could graze lucerne only and be finished on the low cost spring feed, rather lambing earlier and grazing expensive autumn saved pasture or winter feed as is currently happening on 60% of the surveyed lucerne farms.

5.8 Greenfeed and pasture renewal

Two distinct winter feeding groups emerged for the survey responses. The winter greenfeed requirements of those that wintered dairy cows or farmed deer (18% of the farmers surveyed) were greater than the traditional sheep and beef farmers (82%) (Figure 24). For both groups annual grass was the predominant feed sown (29.7 % for + dairy cows: 20.4% for - dairy cows), followed by rape turnips and turnips and grass varying between 14% and 18% of the types of greenfeeds sown (Figure 28). The average percentage of the farms' area sown in greenfeed was less on the traditional sheep and beef farms surveyed compared to those that winter grazed dairy cows or that farmed deer (Figure 27). The sheep farmers surveyed who grazed dairy cows and/ or deer grew 18.3 hectares of winter greenfeed with the average or 9.9% of the total farm area.

The traditional sheep and beef farmers grew 14.7 hectares of greenfeed on average or 7.9% of the total farm area.

The farm area grown in greenfeed or crops other than pasture gives some indication of how often pastures are renewed. The survey results indicate that if 7.9% of the farm is sown in new permanent pastures each year it will take 12.7 years to renew the pastures on the whole property. Similarly for the farms grazing dairy cows or deer all the pastures will be renewed every 10.1 years. When asked how often they renew their pastures, the survey farmers indicated the average age of pasture when renewed was 9.9 years for lucerne and 11.6 for pasture farmers (Tables 4 and 5). The pasture white clover content was around 20% in young pastures and declined to nearer 10% in 3-4 years, the red clover content of pastures during the same period was 25 or less. Despite the lack of production and persistence 97% the farmers sowed white clover and 38% sowed red clover. To maintain a high pasture legume content, dryland farmers surveyed need to renew pastures more frequently than they do currently (9.9 years for lucerne properties or 11.6 for no-lucerne) or alternatively they could sow more persistent legume species in their pasture mixes. Another (more costly) approach would be to oversow clovers into pastures every 5 to 6 years.

Tom Fraser (2000) in an address to the New Zealand Grasslands Conference stated "The first three years of a pasture's life gave the best animal performance. So farmers should not be concerned when lamb finishing pastures last only 3-4 years, so long as they grow plenty of good quality herbage." Mr Fraser (2000) also went on to say that if farmers are sowing less grass they should increase the clover sowing rates". The increased clover content increases the overall nitrogen fixation, which increases the production of the companion pasture plants, as long as moisture is not limiting.

The overall farm production on the dryland farms surveyed in this study could be greatly enhanced by an increase in the frequency of their pasture renewal programmes leading to an increase in the herbage quality and legume content.

Limitations to data:

This research study has highlighted the lack of recent scientific data available regarding herbage production, seasonality and animal performance for many of the current pasture species alternatives now available for dryland, drought-prone farms. With increased usage and efficiencies in irrigation management the emphasis of research has moved away from dryland production systems to increasing the efficiencies of higher producing irrigated properties. However, scientists are predicting increased global climate warming which will result in more extreme climatic variations, a greater number of more intense droughts and less snowfall. The net result for the east coast of New Zealand is the extension the boundaries of drought susceptible regions and less snowfall to recharge irrigation aquifers meaning that irrigation water may become a more limited resource.

The most recent lucerne production data available is from the research conducted in the 1970's to the early 1980's and most of it focussed on the Wairau cultivar. In the past 20 years many new lucerne cultivars have been bred with superior production, increased seasonal range of growth plus greater pest and disease resistance than Wairau possessed. The competitive advantage of the more recent, superior lucerne cultivars over ryegrass/white clover could therefore be greater than this study indicates.

There is almost no pasture production data available for the more recently introduced sub clover cultivars, grown in pasture swards, on dry light land soils under New Zealand climatic conditions. The sub clover based pasture growth rates used in this study for the linear program are the best estimates made by the author based on the small amount of unpublished research data available.

Most of the available sub clover pasture growth rates are based on pure stands grown in Australia under more extreme environments than here in New Zealand.

Chapter 6 Summary & Conclusions

To optimise their total annual pasture production, without complicating the pastoral management too greatly, farmers in drought prone, dryland regions should grow between 25% and 50% of their properties in lucerne (where the soil types allow) depending on the length of winter and the amount of winter greenfeed required. The rest of the property should have sub clover in the pasture mixes, sown at the recommended rates. Lucerne is capable of producing at least 50% more dry matter in seven months than the amount that ryegrass/white clover produces annually. With the exception of spring, the feed quality and palatability of lucerne exceeds that of ryegrass and white clover, where it is managed well. On the interview farms with lucerne, the lambing percentage was 146% compared those farmers that grew no lucerne and achieved 123% lambing. This 23% increase in lambing may be attributed to the better nutrition available to breeding ewes, resulting in higher liveweights and increased fecundity. This was achieved on properties where on average only 17% of their farm area was in lucerne, so the reproductive advantage and stock carrying capacity is likely to be greater for properties with around 34% of their area in lucerne - particularly if they delayed lambing until September.

White clover fails to persist in these drought prone environments. Although the farmers surveyed estimated that white clover persists for 6.2 years on average, they only renew their pastures every 9.9 years on lucerne farms and 12 years on 'no lucerne' properties. Red clover fails to contribute significantly to pasture production, so if these farms have no sub clover, the grass component of the pastures is spending up to half of its life growing without companion legumes to boost their production and improve the overall pasture quality. Farmers finishing lambs on these older pastures would struggle to obtain sufficient liveweight gains to finish lambs quickly, except that sub clover will support the system.

Overall the surveyed farmers believed that sub clover persists in pastures for 15.4 years on average. Sub clover constituted 8.4% of the pasture cover on surveyed farms and 37.5% on average on the interview farms for the total life of the pasture. Over 60% of the farmers with sub clover in their pastures believed it persisted indefinetly and never sow it in their pasture mixes. To maintain a high legume content in dryland pastures, farmers should sow sub clover at the recommended rates of 6-10 kg/ha, instead of red clover, but in conjunction with white clover. The additional money required to be spent on sub clover seed could come from reducing the amount of grass seed sown. The additional nitrogen fixation from clovers will enhance the production of the companion grass species in the pasture sward, allowing it to become more vigorous and dense over time.

The linear programme suggested that farm with 34% lucerne would be best managed if the rest of the farm comprised of 56% ryegrass/ sub clover based pastures and 10% greenfeed. The lucerne should be sown on the best soils on the farm and traditional grass/sub clover/ white clover pastures on the rest. The area in lucerne should be managed separately to the 66% in pasture and greenfeed. Lucerne is best established by ploughing and sowing in spring, generally in September. Lime should be applied if necessary to ensure the soil pH exceeds 6.5 to achieve maximum production, grazing should not commence before the last week in September and rotational grazing is essential.

Sub clover, in contrast to lucerne, is capable of producing well at soil pH 5.5 (or less), should be sown in autumn (February or March), is cool season active and performs best under set stocking. Sub clover production peaks in October then declines as the plant becomes reproductive. Sub clover most actively grows during the cool season, the time when lucerne is dormant and should not be grazed. If dryland farmers grow 10% greenfeed and begin grazing it in mid winter they should have sufficient feed for their ewes for 6-10 weeks. Whilst the greenfeed is being grazed the sub clover based pasture will be actively growing and should provide sufficient high quality feed for lactating ewes until at least the end of September when the lucerne grazing may commence. Technically the system should work well, provided the farmers manage both their lucerne and their pastures optimally.

One of the main issues that the survey highlighted was that most lucerne farmers are good at managing either their lucerne or their other pastures, but not both.

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Appendices

Appendix 1

Postal Questionnaire

Section A

1. Please enter your farm location:

Road:____

Rural area:____

2. Please indicate your type of farm:

❑ Sheep ❑ Beef ❑ Deer ❑ Cropping

❑ Sheep and beef ❑ Mixed (tick as many boxes as necessary)

Total farm area: __________ hectares

Effective area: __________ hectares

Area of flats: __________ hectares

Area of cultivatable rolling country: __________ hectares

Area of steep hill: __________ hectares

Area of the farm irrigated: __________ hectares

3. Please estimate your farm soil type(s) and approximate areas of each:

a) ____________ soil ______ hectares ______ % stone in topsoil

b) ____________ soil ______ hectares ______ % stone in topsoil

c) ____________ soil ______ hectares ______ % stone in topsoil

d) ____________ soil ______ hectares ______ % stone in topsoil

e) ____________ soil ______ hectares ______ % stone in topsoil

f) ____________ soil ______ hectares ______ % stone in topsoil

4. Please enter the animal numbers carried during the winter 2000 in the following table (where relevant):

				Anticipated numbers for this year			
	Number of animals wintered (On 30/6/2000)	Starting date Of Lambing/ Calving etc	Finishing date of Lambing/ Calving	Lambing/ Calving % weaned	Sales Number -stores or breeding	Sales Numbers for slaughter	Number of lamb/calf.... Replacements Retained
Sheep							
Beef							
Deer							
Pigs							
Goats							
Horses							

5. Please provide details of your most recently sown (Most commonly sown cultivars in the last 4-5 years?) (a) pasture, (b) lucerne and (c) feed crops by completing each of the boxes below as is relevant to your situation.

(a) Average areas and sowing rates of new permanent pastures sown in last four to five years-if any?

Area sown (ha or acres?)	Age (years) and type of previous pasture	Cultivation method used (e.g. plough, direct drill/ surface work)	Grass Type and Sowing Rate (kg/ha)	Legume type and Sowing Rate (kg/ha)	Sowing date	Following crop planned and year to be sown	Cultivation method to be used to establish next crop
16 ha	*Eight* *Grass / white clover*	*Ploughed*	*Nui @ 8 kg/ha* *+ Cocksfoot @ 6 kg/ha*	*Huia White clover 3kg/ha + Sub clover 2 kg/a*	*1st Oct 1998*	*Turnips 2000*	*Ploughing*

(b) New lucerne pastures sown in last four to five years-if any?

Area sown (ha or acres?)	Age (years) and type of previous Pasture	Cultivation method used (e.g. plough, direct drill/ surface work)	Lucerne species and Sowing Rate (kg/ha)	Sowing date	Following crop planned and year to be sown
16 ha	*Eight yrs* *Grass/ White clover*	*Ploughed*	*14 kg/ha*	*1st Oct 1998*	*Turnips in the year 2000*

(c) What new summer or winter feed crops have you sown in the last four to five years- if any?

Area sown (ha or acres?)	Age (years) and type of previous Pasture	Cultivation method used (e.g. plough, direct drill/ surface work)	Crop sown and Sowing Rate (kg/ha)	Sowing date	Following crop planned and year to be sown
16 ha	*Eight yrs* *Grass/ White clover*	*Ploughed*	*Rape*	*1st Oct 1998*	*Turnips 2000*

(d) Other new crops e.g. brassicas/ cash crops sown in last four years-if any?

Area sown (ha or acres?)	Age (years) and type of previous Pasture	Cultivation method used (e.g. plough, direct drill/ surface work)	Lucerne species and Sowing Rate (kg/ha)	Sowing date	Following crop planned and year to be sown
16 ha	*Eight yrs* *Grass/ White clover*	*Ploughed*		*1st Oct 1998*	*Turnips 2000*

6. Please give details of your most recent soil tests and indicate when these tests were carried out?

Crop	Soil type (if known)	Date of test	pH	Calcium (Ca)	Phosphorus (P)	Potassium (K)	Sulphur (S)	Magnesium Mg	Sodium Na
Example: Lucerne	*Wakanui*	*10/4/2000*	*6.2*	*8*	*20*	*6*	*12*	*11*	*7*

7. Please indicate the use of lime and fertiliser per year, applied over the last 4 to 5 years. Enter the rate used per hectare and the total area that each type was applied to.

Fertiliser/lime applied	Pastures	Area applied	Lucerne	Area applied	Green feed	Area applied	Other crop	Area applied
Example: Lime (tonnes/ha)	*2 tonnes*	*40 hectares*	*100 tonnes*	*40 hectares*	*10 tonnes*	*20 hectare s*	Brassicas 10 tonnes	5 hectares
Lime (tonnes/ha)								
Superphosphate (kg/ha)								
Sulphur super (kg/ha)								
Potassic super (kg/ha)								
D.A.P (kg/ha)								
Sulphate of ammonia (kg/ha)								
Cropmaster 15 (kg/ha)								
Cropmaster 20 (kg/ha)								
Urea (kg/ha)								
Other (kg/ha) (please specify)								

Section B

Management of lucerne and white clover, or subterranean clover pastures

Please indicate the current area of the farm that is under each of the following pasture species:

(A) Lucerne ____________ (ha)
(B) Sub clover (pure or in pasture mixes) ____________ (ha)
(C) White clover (pure or in pasture mixes) ____________ (ha)
Note: The term "White clover" or "Subterranean clover" pastures refers to the most dominant legume present within the pastures in **spring**.
Please allocate paddocks to either: a) White clover dominant
OR b) Subterranean clover dominant

(A) Management of Lucerne

1. Lucerne - total area sown on average each year?

_______(ha)

2. What is the average age of lucerne when renewed?

_____ years

3. Please give the average area of lucerne that is cut for conservation per year. Please indicate the average number of cuts taken each year from lucerne.

Cuts	Pasture type	Area
Example *twice*	*lucerne*	*20 ha*
one		
two		
three		
four		
five		

4. Please indicate your grazing management for lucerne in the following table:

	Spring (Sept-Nov)	Summer (Dec-Feb)	Autumn (Mar-May)	Winter (June-Aug)
Total number of grazings of lucerne				
Approximate duration of each grazing (days)				
Grazing pressure (stock numbers/ ha/ grazing)				
Pest control (spray type and rate used)				
Weed control (spray type and rate used)				

5. Please show the percentage of lucerne paddocks allowed to flower over summer?

_____ %

6. What number (or %) of animals get red gut?

Number = ___ or ____ %

7. What control methods do you use to prevent red gut? ____________________

____

8. Do you use salt blocks or sodium supplements when grazing lucerne?

❑ Yes ❑ No (please tick appropriate box)

(B) Management of white clover

1. What area of white clover based pastures do you cut for conservation per year? (e.g. hay, silage, balage etc)

_______ ha

2. Please provide details of any special grazing management you use to enhance your white clover production?____

____

3. **What cultivars of white clover have been sown on your property in the past twenty years (if known)?**

Years	White clover cultivars							
	Huia	Pitau	Tahora	Sustain	Prop	Prestige	Demand	Other(s) (please state)
Example 1980's		✓		✓				
1980's								
1990-95								
1995-2000								
Currently sown								

4. **Do you sow innoculated white clover seed?** (please tick appropriate box)

❑ **Yes** ❑ **No** ❑ **Not applicable** (do not sow white clover)

5. **What method of cultivation do you use when sowing white clover?**

❑ **Ploughing** ❑ **Surface working** ❑ **Direct drilling** ❑**Broadcast** ❑ **Other? ________**

6. **Please estimate the number of years white clover persists in your pastures?**

_____ years

7. **Please define your usual white clover grazing management in the following table:**

		Spring (Sept-Nov)	Summer (Dec-Feb)	Autumn (Mar-May	Winter (June-Aug)
Number of grazings of white clover					
Approximate duration of each grazing(days)					
Stock numbers per ha per grazing	- ewes & lambs				
	- ewes				
	- lambs				
	- cattle				
Pest control (spray type and rate used)					
Weed control (spray type and rate used)					

8. Please estimate the total white clover percentage in your white clover pastures in spring (October), for the various age groups of pastures (place one tick in each column as appropriate)**?**

Percentages of White Clover in pastures (%)	1-3 years	4-6 years	7-9 years	Older pastures
0 - 5				
6 - 10				
11 - 20				
21 - 30				
31 - 40				
41 - 50				
51 - 70				
70 - 100				

(C) Management of subterranean clover

1. What area of subterranean based clover pastures do you cut for conservation per year? (hay, silage, balage etc).

________ha

2. Please describe any special grazing management you use to enhance subterranean clover production?____________________________________

____

3. Do you sow innoculated subterranean clover seed? Please tick appropriate box.

❑**Yes** ❑**No** ❑ **Not applicable** (do not sow sub clover at all)

4. What cultivars of subterranean clover have been sown on your property in the past twenty years (if known)?

Years	Subterranean clover cultivars							
	Tallarook	Mt Barker	Woogenellup	Trikkala	Howard	Goulburn	Denmark	Other (please state)
Example: 1990-95		✓				✓		
1980's								
1990-95								
1995-99								
Currently								

5. **Please indicate the method of cultivation you use when sowing subterranean clover?**

❑ Ploughing ❑ Surface working ❑ Direct drilling
❑Broadcast ❑ Other ________ ❑ Not applicable

6. **Please try to estimate the number of years subterranean clover persists in your pastures?**

____ years

7. **Please define your usual grazing management of subterranean clover in the following table:**

		Spring (Sept-Nov)	Summer (Dec-Feb)	Autumn (Mar-May	Winter (June-Aug)
Number of grazings					
Approximate duration of each grazing (days)					
Stock numbers per ha per grazing	- ewes & lambs				
	- ewes				
	- lambs				
	- cattle				
Pest control (spray type and rate used)					
Weed control (spray type and rate used)					

8. **Please estimate the subterranean clover percentage in your pastures ? (please place one tick in each column as appropriate)**

Percentage of Subterranean Clover in pasture (%)	1-3 years	4-6 years	7-9 years	Older pastures
0 - 5				
6 - 10				
11 - 20				
21 - 30				
31 - 40				
41 - 50				
51 - 70				
71 - 100				

(D). Greenfeed crops and supplementary feeding

1. What area and what type of supplementary feed do you grow?

Example: Type__Turnips______ Area__20 ha______

Type__________ Type__________ Type__________

Area__________ Area__________ Area__________

2. How much additional supplementary feed do you use?

Hay____________________(kg /tonnes)

Silage ____________________(kg /tonnes)

Off-farm grazing____________________(sheep/cattle grazing days)

Example: *800 ewes for 60 days = 48,000 sheep grazing days*

3. Please indicate the importance of greenfeeds and supplementary feeds in the following table (including purchased feeds) :

	Spring	Summer	Autumn	Winter
Example 1 *600 Ewes on turnips* *Annual ryegrass*		*400 small bales ryegrass straw*		*6 hectares @ 12 tonnes/ha* *800 small bales meadow hay*
Hay (tonnes)				
Silage/balage (tonnes)				
Concentrates (tonnes)				
Annual ryegrass				
Cereal crops				
Rape				
Turnips				
Other (please state)				

If wish to receive a copy of the summary report, or you are prepared to be contacted at a later date, for further discussions regarding this survey, then please fill in you name and telephone number below :

Farmer's name(s):____________________

Telephone number:____________________

Email : ____________________

Appendix 2

Long term climatic data for Winchmore irrigation research station, Canterbury

AgResearch Winchmore - Total monthly rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Sep-Apr
1950	75.3	87.4	43.3	76.8	21.1	46.7	42.2	115	22.2	119.2	49.7	109.1	808	583
1951	116.7	133.6	143.2	124.4	23.9	34.6	32.6	30.3	10.6	97.2	55.3	123.8	926.2	804.8
1952	49.8	24.4	24.1	16.3	54.3	50.3	29.9	92.3	47.5	108.1	251.9	86.7	835.6	608.8
1953	143.5	47.4	130.4	112.9	34.7	30.5	35.4	75	35.9	97.5	24.3	95.2	862.7	687.1
1954	17.5	34.8	71.7	35.6	34.2	36	90.7	112.2	23.1	16.8	40.5	149.1	662.2	389.1
1955	22.9	64.9	50.1	4.5	82.6	85.7	138	25.3	42.1	34	85.6	17.6	653.7	321.7
1956	52.4	25.8	72.4	58	61.3	21.2	112	43.3	87.1	113.2	99.2	63.8	809.3	571.9
1957	55.2	58.2	141.4	100.4	148.4	34.7	93.1	16.2	87.1	37.7	70.6	99	942	649.6
1958	88.1	72.1	48.8	75.6	47.3	42.4	13.6	22.7	11.2	87.8	28.1	58.1	595.8	469.8
1959	32.4	75.4	157.4	54.1	242.2	20.5	56.4	12.2	11.8	63.1	32.6	73.2	831.3	500
1960	29.8	31.9	61.4	60.1	19.1	135.9	29.6	64.3	39.8	44	84	76	675.9	427
1961	95.6	95.7	48.8	56.8	138.6	42.6	95.5	131.6	62.2	8.4	35.2	28.5	839.5	431.2
1962	61.1	68.7	72.6	77.7	77.7	59.1	49.2	48.9	27.8	55.5	90.6	44.2	733.1	498.2
1963	52.8	113.5	34.4	124.4	39.2	55.4	175	81.1	50.9	17.9	62.4	59	865.5	515.3
1964	24.1	6.8	56.1	25.4	127.8	18.2	51	35.9	30.4	16.5	62.8	43.1	498.1	265.2
1965	129.3	40.8	105.1	97.1	37	61.1	62.9	30.5	36.7	45.2	102.4	54	672.8	610.6
1966	63.3	51.4	75.4	47.9	71.2	2.4	71	96.2	18.3	78.1	78.9	58.7	712.8	472
1967	60.6	37.5	58.1	62.8	45.1	16.8	20.9	77.8	33.4	86.5	162.8	26.9	689.2	528.6
1968	66.6	63.3	49.1	218.6	32.9	56.5	124	21.6	72.1	32.9	60.8	87.3	885.5	650.7
1969	51.2	29.3	19.5	58.9	48.1	13.5	34.6	34	29.1	35.7	13.1	120	487	356.8
1970	75	34.6	97.3	13.3	62.2	87.6	62.2	41.7	68.1	33	42.5	46.7	664.2	410.5
1971	46.3	26.7	20.2	19.5	74.1	108.1	56.8	36.1	43.1	47.5	31	31	540.4	265.3
1972	70.2	30.1	28.9	67.6	95	42.8	49.3	28.2	15	101.4	40.8	51.4	620.7	405.4
1973	34.3	23.9	34.6	31	49.7	43.3	34.8	228.1	27.6	29.2	42	64.6	643.1	287.2
1974	40.7	103.8	66.2	186.1	65.9	42.9	56.1	64.1	84.6	103.2	6.7	36.4	856.7	627.7
1975	127.7	81.4	75.4	62.9	15.1	112.8	46.6	161.1	41.8	73.4	50	27.6	875.8	540.2
1976	42	70.6	28.8	31.8	35.6	55.2	38.4	70.2	74.1	65.2	45.6	123.1	680.6	481.2
1977	59.5	58.4	8.3	49.6	53.3	101.8	78.9	59.5	95.1	23.3	24.1	73.1	684.9	391.4
1978	51.2	19.5	36.5	247.5	50.5	93.6	132	73.6	159.3	91.4	36	124.2	1115.4	765.6
1979	39.2	42.2	171.8	8.8	168.6	6.3	55	112.6	27	136	66.9	48.5	882.9	540.4
1980	124.7	68.3	108.6	123.6	11.7	76.1	50.7	47.2	7.9	47.1	118.4	49.9	834.2	648.5
1981	33.4	22.6	52	39.5	20.3	84.1	101	103.6	14.7	95.9	27.7	49.9	644.3	335.7
1982	23.6	31.6	15.8	66.7	20.7	57.5	22.9	32.1	38.7	116.6	50.8	79.9	556.9	423.7
1983	38.7	15.3	43	122.4	66.9	36.7	63.8	31.3	118.4	40.3	27	104.5	708.3	509.6
1984	96.2	77.9	139	21.7	47.6	7.4	73.5	32.9	20.9	25.5	69.1	53.8	665.5	504.1
1985	10.5	73.7	36.9	12.4	68.7	48.2	63.2	65.4	39	50.6	98.6	97	664.2	418.7
1986	44.2	114.5	144.4	13.4	50.7	31.8	146	168.8	53.6	111.9	98.5	13.1	990.9	593.6
1987	8.4	121.7	173	28.7	92.7	53	50	29.5	32.2	74.5	67.6	49.8	781.1	555.9
1988	60.8	49.1	11.3	27.3	55.2	41.4	36.9	46.4	2.5	11	35.9	29.3	407.1	227.2
1989	77.2	30.1	36.1	58	128.4	59.4	38.5	52.1	27.6	94	34	87.7	723.1	444.7
1990	37.7	34.8	42.1	25.3	77.3	22.5	54.5	121.3	46.1	62.5	65.5	49.4	639	363.4
1991	59.8	65.9	35	65.4	40.9	78.9	72.4	23.4	58.2	33	66.8	109.6	709.3	493.7
1992	25.9	22.3	4.2	27.5	80.7	35.8	103	137.9	101.2	83.7	48.6	73.9	744.5	387.3
1993	55.1	39.5	57.5	105.7	86.9	19.8	0.5	13.4	135.5	25.9	93.1	91.1	724	603.4
1994	53.5	69.7	149.8	17.7	29	68.1	105	8.7	91	23.7	38.4	27.3	681.8	471.1
1995	55.4	30.7	59.9	60.2	36.1	258.7	23	44.3	118.1	65.4	47.8	48.9	848.5	486.4
1996	39.1	114.4	89.1	72	42.6	78	159	55	12.2	63.2	39.8	41.6	806.2	471.4
1997	103.2	37	97.6	64	53	38.2	35.6	83.4	43.4	50.6	33.4	58.8	698.2	488
Mean	59	56	69	66	64	55	66	65	50	62	61	67		

30-Apr-1998

AgResearch Winchmore

10cm Dryland soil temperature ($^{\circ}C$)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1970	17.8	15.7	15.0	11.7	7.1	4.4	4.3	5.6	8.2	11.0	13.9	16.1	10.9
1971	17.4	17.6	15.4	11.1	9.0	6.1	3.5	5.3	7.6	10.2	13.2	16.9	11.1
1972	16.7	15.9	14.7	11.1	6.8	3.0	3.1	3.6	7.8	10.5	14.3	14.0	10.1
1973	17.1	17.7	14.4	10.6	7.6	4.2	3.3	4.3	8.1	10.7	14.0	16.1	10.7
1974	16.0	16.6	13.4	11.7	7.4	3.5	4.0	4.5	7.9	10.8	14.1	16.8	10.6
1975	18.1	16.6	15.0	12.3	8.3	4.4	2.9	5.6	7.5	10.3	12.3	14.6	10.7
1976	15.8	14.1	14.0	11.1	6.5	3.7	2.7	5.0	7.3	9.3	11.6	14.6	9.6
1977	14.8	15.5	14.3	10.8	6.3	4.3	4.6	5.4	6.3	10.8	12.6	15.0	10.1
1978	17.0	17.1	15.3	13.4	9.1	4.9	4.9	5.9	8.0	11.0	13.2	15.8	11.3
1979	16.7	16.7	14.8	11.2	7.8	5.1	4.8	5.2	8.1	10.9	14.2	15.3	10.9
1980	16.1	15.9	13.7	11.8	8.6	4.9	3.9	4.9	8.0	11.5	12.4	15.5	10.6
1981	17.7	17.4	15.1	12.1	7.9	6.3	4.3	4.6	6.3	10.4	14.0	16.7	11.1
1982	17.4	17.6	15.9	10.0	7.6	4.8	2.9	5.1	8.0	9.7	13.9	15.0	10.7
1983	15.6	16.1	14.3	11.1	8.2	4.9	4.1	5.4	7.4	11.1	13.4	14.8	10.5
1984	15.6	15.8	15.4	11.9	7.3	5.3	5.1	6.2	9.0	11.1	14.9	16.5	11.2
1985	18.8	17.7	14.9	12.2	8.2	5.7	4.8	5.1	8.4	10.6	13.7	16.2	11.4
1986	18.1	16.9	15.1	12.4	8.1	4.8	3.2	4.3	7.2	11.5	14.6	16.6	11.1
1987	19.0	16.6	14.6	11.7	9.4	6.5	5.0	6.9	8.4	10.7	14.5	14.9	11.5
1988	16.7	16.2	13.6	9.8	5.5	4.1	4.1	4.7	8.5	10.6	14.2	17.1	10.4
1989	18.0	16.4	14.8	10.8	7.8	4.5	2.6	5.5	8.8	11.4	14.0	15.4	10.8
1990	16.8	17.8	14.5	11.3	7.7	5.0	4.0	5.3	7.4	10.7	13.3	15.6	10.8
1991	16.7	15.6	14.6	10.9	6.9	3.8	2.3	5.0	8.4	9.9	12.2	15.0	10.1
1992	17.0	16.0	13.8	10.3	6.3	3.9	3.5	4.6	6.1	9.8	14.1	14.8	10.0
1993	15.7	15.3	13.9	10.2	7.1	5.7	3.8	4.8	7.1	11.6	12.0	14.5	10.1
1994	16.9	17.2	13.9	11.4	7.9	4.4	3.4	5.1	7.3	9.7	13.4	16.1	10.6
1995	16.9	17.1	14.6	12.8	8.4	5.2	2.2	4.3	7.2	10.9	13.4	16.2	10.8
1996	17.6	16.5	13.4	11.0	7.1	4.0	3.6	4.3	8.2	11.5	12.9	15.3	10.5
1997	16.1	17.1	13.7	10.5	8.8	5.1	3.3	4.7	7.3	10.6	13.3	15.4	10.5
1998													
1999													
Mean	16.9	16.5	14.5	11.3	7.7	4.7	3.7	5.0	7.7	10.7	13.5	15.6	10.7
Highest	19.0	17.8	15.9	13.4	9.4	6.5	5.1	6.9	9.0	11.6	14.9	17.1	11.5
Lowest	14.8	14.1	13.4	9.8	5.5	3.0	2.2	3.6	6.1	9.3	11.6	14.0	9.6

Appendix 3 Linear programming Model

a) Model assumptions

Recommended Seed Mixes

	Sowing rate (kg/ha)	Seed Cost (per kg)	Cost per ha
Lucerne			
Pioneer W5454 superstrike	8 kg	$16.80	$134.40
	Total lucerne seed costs/ha		**$134.40**
Ryegrass/White Clover			
Meridian AR 1	8 kg	$6.35	$50.80
Huia white clover (Prill coated)	3kg	$3.75	$11.25
Pawera red clover (Prill coated)	2kg	$7.20	$14.40
	Total ryegrass/ white clover seed costs/ha		**$76.45**
Ryegrass/White Clover			
AR 1	8 kg	$6.35	$50.80
Huia White clover (Prill coated)	2 kg	$3.75	$11.25
Woogenellup Subterranean clover	10 kg	$5.30	$53.00
	Total ryegrass/ sub cloverseed costs/ha		**$115.05**

Annual costs of pasture and lucerne renovation and maintenance with maintenance fertiliser every 2nd year

				Actual Costs	Total Annual Costs
(Renewed	Lucerne costs per hectare per year every 8 years)				
Establishment					
Plough				$ 65.00	
2.5 tonnes Lime		$35.00/tonne		$ 87.50	
Lime application cost		$8.00/tonne		$ 20.00	
Surface work				$ 35.00	
Surface work and roll				$ 40.00	
Spray with Treflan		2litres @$10.50/l		$ 21.00	
Spray Application		$12.50/pass		$ 12.50	
Lucerne Seed and Innoculant				$ 134.40	
Drilling Costs				$ 40.00	
250 kg/ha Molybdic Super				$ 47.50	
			total	$ 502.90	$ 62.86
Maintenance	(every 2 years)				
30% Potassic Super	500kg/ha	at $239.20/tonne		$ 119.60	
Spreading Costs		$6.50/pass		$ 6.50	
				$ 126.10	
Maintenance	(every 4 years)				$ 63.05
Paraquat	2 litres	$22.27/litre		$ 44.54	
Atrazine	1.5 litres	$9.55/litre		$ 14.33	
Application		$12.50/pass		$ 12.50	
2.5 tonnes lime		$35.00/tonne		$ 70.00	
Lime application cost				$ 20.00	
				$ 161.37	$ 40.34
		Lucerne Total Annual Costs			$ 166.26

				Actual Costs	Total Annual Costs
	Ryegrass/white clover costs per hectare per year (Renewed every 8 years)				
Establishment					
Glyphosate		2 litres/ha	$13.00/litre	$ 26.00	
2 tonnes lime		$35.00/tonne		$ 70.00	
Lime application		$8.00/tonne		$ 16.00	
Chisel Plough		$40/ha		$ 40.00	
Seed				$ 76.45	
Drill				$ 40.00	
250 kg/ha Superphosphate		at $182/tonne		$ 45.50	
			Total	$ 313.95	
					$ 39.24
Pasture annual maintenance costs					
		Pasture annual maintenance costs			
Maintenance	(every 2 years)				
Superphosphate	500kg/ha	at $166.40/tonne		$ 83.20	
Spreading Costs		$6.50/pass		$ 6.50	
Application		$12.50/pass		$ 12.50	
Topping once year for barley grass	$25/pass			$ 25.00	
				$ 127.20	$ 63.60
Maintenance	(every 4 years)				
Spray for thistles	2 litres/ha Tropotox @ $10.71/litre			$ 21.42	
2.0 tonnes lime		$35.00/tonne		$ 70.00	
Lime application cost				$ 20.00	
				$ 111.42	$ 27.86
		Ryegrass/white clover Annual Costs			$ 130.70

				Actual Costs	Total Annual Costs
	Ryegrass/Sub clover costs per hectare per year (Renewed every 8 years)				
Establishment					
Glyphosate		2 litres/ha	$13.00/litre	$ 26.00	
2 tonnes lime		$35.00/tonne		$ 70.00	
Lime application		$8.00/tonne		$ 16.00	
Chisel Plough		$40/ha		$ 40.00	
Seed				$ 115.05	
Drill				$ 40.00	
250 kg/ha Superphosphate		at $182/tonne		$ 45.50	
			Total	$ 352.55	
					$ 44.07
Ryegrass/Sub Clover Annual Maintenance Costs					
Maintenance	(every 2 years)				
Superphosphate	500kg/ha	at $166.40/tonne		$ 83.20	
Spreading Costs		$6.50/pass		$ 6.50	
Application		$12.50/pass		$ 12.50	
Topping once year for barley grass	$25/pass			$ 25.00	
			Total	$ 127.20	$ 63.60
Maintenance	(every 4 years)				
Spray for thistles	2 litres/ha Tropotox @ $10.71/litre			$ 21.42	
2.0 tonnes lime		$35.00/tonne		$ 70.00	
Lime application cost				$ 20.00	
			Total	$ 111.42	$ 27.86
		Ryegrass/Sub clover Annual Costs			$ 135.52

Annual costs of pasture and lucerne renovation and maintenance with maintenance fertiliser every 4th year

				Actual Costs	Total Annual Costs
Lucerne costs per hectare per year (Renewed every 8 years)				Actual Costs	Total Annual Costs
Establishment					
Plough				$ 65.00	
2.5 tonnes Lime		$35.00/tonne		$ 87.50	
Lime application cost		$8.00/tonne		$ 20.00	
Surface work				$ 35.00	
Surface work and roll				$ 40.00	
Spray with Treflan		2litres @$10.50/l		$ 21.00	
Spray Application		$12.50/pass		$ 12.50	
Lucerne Seed and Innoculant				$ 134.40	
Drilling Costs				$ 40.00	
250 kg/ha Molybdic Super				$ 47.50	
			total	$ 502.90	$ 62.86
Maintenance	(every 2 years)				
30% Potassic Super	500kg/ha	$239.20/tonne		$ 119.60	
Spreading Costs		$6.50/pass		$ 6.50	
				$ 126.10	
Maintenance	(every 4 years)				$ 63.05
Paraquat	2 litres	$22.27/litre		$ 44.54	
Atrazine	1.5 litres	$9.55/litre		$ 14.33	
Application		$12.50/pass		$ 12.50	
2.5 tonnes lime		$35.00/tonne		$ 70.00	
Lime application cost				$ 20.00	
				$ 161.37	$ 40.34
			Lucerne Total Annual Costs		$ 166.26
Ryegrass/white clover costs per hectare per year (Renewed every 8 years)				Actual Costs	Total Annual Costs
Establishment					
Glyphosate		2 litres/ha	$13.00/litre	$ 26.00	
2 tonnes lime		$35.00/tonne		$ 70.00	
Lime application		$8.00/tonne		$ 16.00	
Chisel Plough		$40/ha		$ 40.00	
Seed				$ 76.45	
Drill				$ 40.00	
250 kg/ha Superphosphate		at $182/tonne		$ 45.50	
			Total	$ 313.95	
					$ 39.24
Pasture annual manitenance costs					
		Pasture annual manitenance costs			
Maintenance	(every 4 years)				
Superphosphate	500kg/ha	at $166.40/tonne		$ 83.20	
Spray for thistles	2 litres/ha Tropotox @ $10.71/litre			$ 21.42	
2.0 tonnes lime		$35.00/tonne		$ 70.00	
Lime application cost				$ 20.00	
				$ 111.42	$ 27.86
			Ryegrass/white clover Annual Costs		$ 67.10
Ryegrass/Sub clover costs per hectare per year (Renewed every 8 years)				Actual Costs	Total Annual Costs
Establishment					
Glyphosate		2 litres/ha $13.00/litre		$ 26.00	
2 tonnes lime		$35.00/tonne		$ 70.00	
Lime application		$8.00/tonne		$ 16.00	
Chisel Plough		$40/ha		$ 40.00	
Seed				$ 115.05	
Drill				$ 40.00	
250 kg/ha Superphosphate		at $182/tonne		$ 45.50	
			Total	$ 352.55	
					$ 44.07
Ryegrass/Sub Clover Annual Manitenance Costs					
Maintenance	(every 4 years)				
Superphosphate	500kg/ha	at $166.40/tonne		$ 83.20	
Spray for thistles	2 litres/ha Tropotox @ $10.71/litre			$ 21.42	
2.0 tonnes lime		$35.00/tonne		$ 70.00	
Lime application cost				$ 20.00	
			Total	$ 194.62	$ 48.66
			Ryegrass/Sub clover Annual Costs		$ 92.72

b) Model Results

Linear programme model solutions and sensitivity analysis for increasing lucerne areas with sub clover pastures.

Low lucerne production				
10% farm area in greenfeed	Optimal	17%	50%	70%
Adjusted farm income*	$222,320	$181,330	$203,896	$180,447
Area in each pasture type				
Lucerne	33.5%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	25.8%	0.0%	0.0%
Ryegrass/sub clover	56.5%	47.2%	40.0%	20.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	10.0%	10.0%	10.0%
Lucerne Hay (conventional bales)	4,813	0	17,280	20,858

*Total Farm Gross Margin

5% increase in lucerne production				
	Optimal	**17%**	**50%**	**70%**
10% farm area in greenfeed				
Adjusted farm income*	$227,169	$186,399	$209,526	$188,266
Area in each pasture type				
Lucerne	32.7%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	23.5%	0.0%	0.0%
Ryegrass/sub clover	57.3%	49.5%	40.0%	20.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	10.0%	10.0%	10.0%
Lucerne Hay (conventional bales)	4,960	0	18,719	32,822

*Total Farm Gross Margin

10% increase in lucerne production				
	Optimal	**17%**	**50%**	**70%**
10% farm area in greenfeed				
Adjusted farm income*	$231,749	$191,467	$215,157	$196,084
Area in each pasture type				
Lucerne	31.7%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	21.3%	0.0%	0.0%
Ryegrass/sub clover	58.3%	51.7%	40.0%	20.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	10.0%	10.0%	10.0%
Lucerne Hay (conventional bales)	5,199	0	20,157	35,167

*Total Farm Gross Margin

15% increase in lucerne production				
	Optimal	**17%**	**50%**	**70%**
10% farm area in greenfeed	$236,054	$196,536	$220,787	$203,903
Adjusted farm income*				
Area in each pasture type				
Lucerne	30.8%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	19.0%	0.0%	0.0%
Ryegrass/sub clover	59.2%	44.0%	40.0%	20.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	10.0%	10.0%	10.0%
Lucerne Hay (conventional bales)	5,228	0	21,597	37,060

*Total Farm Gross Margin

20% increase in lucerne production				
	Optimal	**17%**	**50%**	**70%**
10% farm area in greenfeed				
Adjusted farm income*	$240,118	$201,605	$226,381	$211,722
Area in each pasture type				
Lucerne	29.8%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	16.7%	0.0%	0.0%
Ryegrass/sub clover	60.2%	56.3%	40.0%	20.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	10.0%	10.0%	10.0%
Lucerne Hay (conventional bales)	5,356	0	22,966	38,953

*Total Farm Gross Margin

The Linear programme model

Constraint	Supply	Relationship		Lucerne	Ryegr/W.C	Ryegr/SubC	Summer Greenfeed	Winter Greenfeed	Feb/March Feed tie	March/April Feed tie	April/May Feed tie	May/June Feed tie	June/July Feed tie	July/August Feed tie	August/Sept Feed tie
AREA	400	>=	400	1	1	1	1	1							
Janurary	0	>=	-180674.0598	-9765	-2511	-2480	0	0							
Feburary	0	>=	-8.73115E-10	-7392	-2268	-2240	0	0	1						
March	0	>=	-6.40284E-10	-9765	-2573	-2821	0	-3960	-0.85	1					
April	0	>=	-1.74623E-09	-4590	-3000	-4860	0	-6120		-0.85	1				
May	0	>=	1.74623E-10	-3255	-2678.4	-8680	0	-6032.6			-0.88	1			
June	0	>=	-4.24916E-09	-1650	-1710	-4104	0	-3360				-0.85	1		
July	0	>=	2.91038E-10	0	-1767	-3534	0	-8432					-0.9	1	
August	0	>=	-2.03727E-09	0	-2473.8	-8990	0	-8432						-0.95	1
September	0	>=	4.13274E-09	-3300	-8700	-12180	-11340	0							-0.95
October	0	>=	-5559788.667	-38499	-13640	-21762	-17360	0							
November	0	>=	-3.49246E-10	-18000	-9720	-8400	-11550	0							
December	0	>=	-5.82077E-10	-11780	-4687.2	-3766.5	-4743	0							
Lamb/hgt tie	0	>=	-1.7053E-12												
Hgt/2th tie	0	>=	-3.41061E-13												
2th/4th tie	0	>=	-3.41061E-13												
4th/6th tie	0	>=	1.36424E-12												
6th/4yr tie	0	>=	-2.27374E-12												
4yr/5yr tie	0	>=	2.50111E-12												
5 yr plus tie	0	>=	-9.09495E-13												
Female lamb tie	0	>=	3.63798E-12												
Ram lamb tie	0	>=	0												
Wool production (kg)	0	>=	2.91038E-11												
Winter greenfeed	40		40					1							
Hayshed	0	>=	-9.09495E-13												
Lucerne Area	400		134.8576491	1											
C			222320.8464	-$ 166.26	-$ 130.70	-$ 135.52	-$ 126.00	-$ 165.00							
Activity level				134.8576491	0	225.1423509	0	40	0	387419.2156	191309.6684	637002.4925	0	0	220035.8095

Constraint	November Hay (conventional bales)	December Hay (conventional bales)	January Hay (conventional bales)	June (MJME/bale)	Feed Hay July (MJME/bale)	August (MJME/bale)	Sept	Lambs	Hoggets	2th ewes	4th ewes	6th ewes	4 yr ewes	5 yr ewes	Sell ewe lambs	Sell ram lambs	Sell ($/kg)	Sell cull 2ths	Ewes sold after 4 lambings	Ewes sold 5 lambings
		Make Lucerne Hay									Activities									
AREA																				
Janurary			60					0.00	368.28	301.32	301.32	301.32	301.32	301.32				301.32		
Feburary			40					0.00	332.64	272.16	272.16	272.16	272.16	272.16				272.16		
March								0.00	385.02	334.80	334.80	334.80	334.80	334.80						
April								0.00	405.00	421.20	421.20	421.20	421.20	421.20						
May								0.00	418.50	435.24	435.24	435.24	435.24	435.24						
June				-162				10.80	388.80	356.40	356.40	356.40	356.40	356.40						
July					-160			27.00	401.76	368.28	368.28	368.28	368.28	368.28						
August						-158		97.20	368.28	418.50	418.50	418.50	418.50	418.50						
September							-156	162.00	648.00	648.00	648.00	648.00	648.00	648.00						
October	96							194.40	803.52	870.48	870.48	870.48	870.48	870.48						
November	94	80						275.40	712.80	777.60	777.60	777.60	777.60	777.60						
December		110	90					301.32	401.76	401.76	401.76	401.76	401.76	401.76						-401.76
Lamb/hgt tie								-0.98	1											
Hgt/2th tie									-0.98	1								1		
2th/4th tie										-0.97	1									
4th/6th tie											-0.96	1								
6th/4yr tie												-0.96	1							
4yr/5yr tie													-0.95	1					1	
5 yr plus tie														-0.94						1
Female lamb tie								1		-0.58	-0.63	-0.65	-0.68	-0.68	1					
Ram lamb tie										-0.58	-0.63	-0.65	-0.68	-0.68		1				
Wool production (kg)									-3.50	-4.20	-4.50	-4.80	-4.80	-4.60			1			
Winter greenfeed																				
Hayshed	-1	-1	-1	1	1	1	1													
Lucerne Area																				
C	-$ 2.00	-$ 2.00	-$ 2.00					-$2.50	-$3.85	-$4.95	-$4.95	-$4.95	-$4.95	-$4.95	47.6	51	3.85	65	38	26
Activity level	532.3939737	2211.450789	2070.465307	16.91147164	4797.398599	0	0	921.0459368	902.625	884.5725	858.0353	823.7139	790.7654	751.2271	1704.537	2635.583	21940.7	0	0	706.1535

Linear programme model solutions and sensitivity analysis for increasing lucerne areas and no sub clover pastures.

Low lucerne production				
10% farm area in greenfeed	**Optimal**	**17%**	**50%**	**70%**
Adjusted farm income*	$156,852	$144,740	$154,772	$156,775
Area in each pasture type				
Lucerne	90.0%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	60.1%	6.2%	0.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	22.9%	43.8%	10.0%
Lucerne Hay (conventional bales)	45,205	6313	12,719	27,467

*Total Farm Gross Margin

5% increase in lucerne production				
	Optimal	**17%**	**50%**	**70%**
10% farm area in greenfeed				
Adjusted farm income*	$166,905	$146,978	$160,629	$164,594
Area in each pasture type				
Lucerne	90.0%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	58.2%	4.7%	0.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	24.8%	45.3%	10.0%
Lucerne Hay (conventional bales)	53,638	5,935	19,355	29,431

*Total Farm Gross Margin

10% increase in lucerne production				
	Optimal	**17%**	**50%**	**70%**
10% farm area in greenfeed				
Adjusted farm income*	$176,958	$149,216	$166,416	$172,412
Area in each pasture type				
Lucerne	90.0%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	56.4%	3.2%	0.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	26.6%	47.8%	10.0%
Lucerne Hay (conventional bales)	50,071	5,558	14,087	31,252

*Total Farm Gross Margin

15% increase in lucerne production				
	Optimal	**17%**	**50%**	**70%**
10% farm area in greenfeed	$187,011	$151,454	$172,195	$180,231
Adjusted farm income*				
Area in each pasture type				
Lucerne	90.0%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	54.6%	1.7%	0.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	28.4%	48.3%	30.0%
Lucerne Hay (conventional bales)	52,505	5180	14,784	33,145

*Total Farm Gross Margin

20% increase in lucerne production				
	Optimal	**17%**	**50%**	**70%**
10% farm area in greenfeed				
Adjusted farm income*	$197,063	$153,692	$177,974	$188,050
Area in each pasture type				
Lucerne	90.0%	17.0%	50.0%	70.0%
Ryegrass/white clover	0.0%	52.4%	1.3%	0.0%
Summer greenfeed	0.0%	0.0%	0.0%	0.0%
Winter greenfeed	10.0%	31.6%	48.7%	30.0%
Lucerne Hay (conventional bales)	54,938	4803	15,410	35,007

*Total Farm Gross Margin